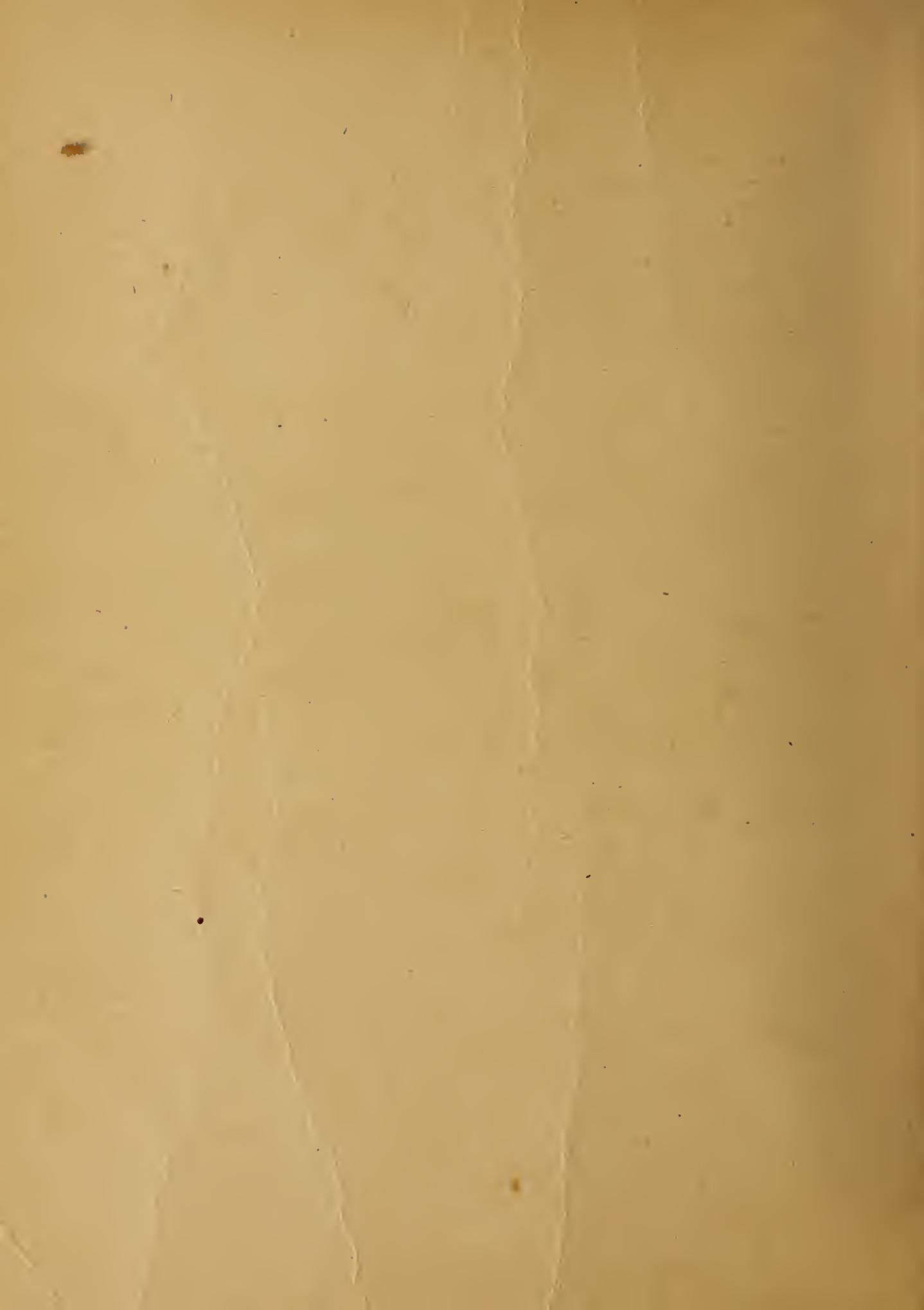


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Skinner

Molecular Rearrangements in the Camphor Series.

The Decomposition Products of the Methyl  
Ester of Isoaminocamphonic Acid



MOLECULAR REARRANGEMENTS IN THE CAMPHOR SERIES.  
THE DECOMPOSITION PRODUCTS OF THE METHYL  
ESTER OF ISOAMINOCAMPHONANIC ACID.

BY

GLENN SEYMOUR SKINNER

A. B. Kansas State Manual Training Normal, 1913

A. M. University of Illinois, 1915

---

THESIS

Submitted in Partial Fulfillment of the Requirements for the

Degree of

DOCTOR OF PHILOSOPHY

IN CHEMISTRY

IN

THE GRADUATE SCHOOL

OF THE

UNIVERSITY OF ILLINOIS

1917



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UNIVERSITY OF ILLINOIS  
THE GRADUATE SCHOOL

May 14 1917

I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPER-  
VISION BY Glenn Seymour Skinner  
ENTITLED Molecular Rearrangements in the Camphor Series. The  
Decomposition Products of the Methyl Ester of Isoaminocamphonan  
Acid.  
BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE  
DEGREE OF Doctor of Philosophy

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Final Examination\*

\*Required for doctor's degree but not for master's.

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## I HISTORICAL

### The Camphors.

The camphors may be regarded as simple oxidation products of a series of hydrocarbons having the empirical formula  $(C_5H_8)_x$ . These hydrocarbons, which together with their oxidation products, form a large number of the essential and naturally occurring oils, may be divided into four main classes:

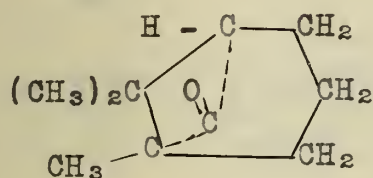
|                      |                |
|----------------------|----------------|
| Hemiterpenes-----    | $C_5H_8$       |
| Normal Terpenes----- | $C_{10}H_{16}$ |
| Sesquiterpenes-----  | $C_{15}H_{24}$ |
| Polyterpenes-----    | $(C_5H_8)_x$   |

Among the most important camphors derived from the normal terpene division are to be found Japan Camphor and Matricia Camphor. They are bicyclic ketones having the general formula  $C_{10}H_{16}O$ , but differing in the fact that one rotates the plane of polarized light to the right and the other an exactly equivalent degree to the left. The common or dextro variety occurs chiefly in the camphor laurel, *Cinnamomum Camphora*, a tree native to Japan, Formosa and central China. Laevo, or Matricia camphor is found in the volatile oil of the feverfew, *Pyrethrum Parthenium*<sup>1</sup>, a European shrub, and in the twigs of the North American sage brush, *Artemesia nana*<sup>2</sup>. A mixture of equal parts<sup>3</sup> of the two gives racemic camphor, which is inactive. Synthetic camphor is also inactive. Victor Meyer<sup>4</sup> first proposed a formula for d-camphor in 1870. Since that time more than thirty

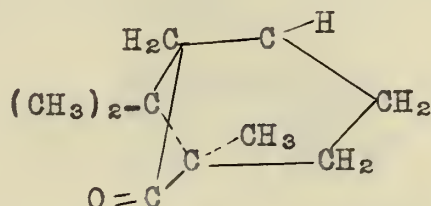
- 
1. Compt. rend., 37, 66
  2. Centr., (1900) 11, 2160
  3. Ber., 12, 1756; 41, 4473
  4. Ber., 3, 121.



formulas have been brought forward by nearly as many investigators, but the one now almost universally accepted is the one proposed by Bredt<sup>1</sup> in 1893. The relation between the two may be represented as follows:



d-Camphor  
M. P. = 178.4°  
D = +42.22°



l-Camphor  
M.P. = 178.4°  
D = -42.22°

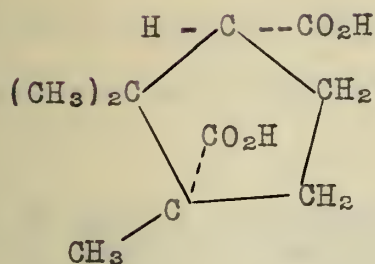
#### THE CAMPHORIC ACIDS.

By oxidation with nitric acid each of the above camphors gives a dicarboxylic acid<sup>2,4</sup>. Upon heating either acid in sealed tubes a partial conversion to an isomeric form<sup>3,5</sup> occurs, in which the secondary carboxyl shifts from the cis to the trans position. A mixture of equal parts of the two original acids gives racemic camphoric acid and a similar mixture of the isomeric acids gives racemic isocamphoric acid. Thirteen camphoric acids are described in the literature, but in 1894 Aschan<sup>6</sup> showed that there are only six.

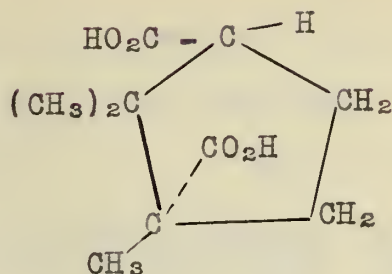
- 
1. Ber., 26, 3049
  2. Ber., 36, 4332.
  3. Compt. rend., 108, 979; J. Ch. Soc., 77, 386; Ber., 26, 1639; 28, 2151; Ann. 309, 341; Ber., 27, 2005; J. Am. Ch. Soc., 32, 1669; 35, 77; 36, 118.
  4. Ann., 316, 210; 127, 121; Compt., rend., 56, 698; 110, 792; Jsb. Chem., 1853, 430; 1863, 556; Ber., 41, 4470; 42, 485.
  5. Ann., 316, 211; Compt., rend., 110, 792; Ber., 27, 2005.
  6. Ann., 127, 121; Compt., rend., 56, 698; Ber., 12, 1756; 105, 66, 29, 1700; Compt., rend. 108, 979; Ber., 27, 2001.



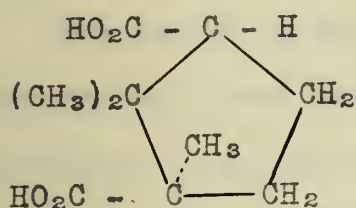




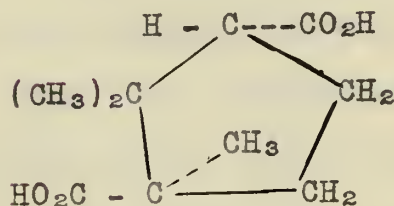
d-Camphoric Acid  
M.P. =  $187^{\circ}$   
 $\alpha_D = +49.7^{\circ}$



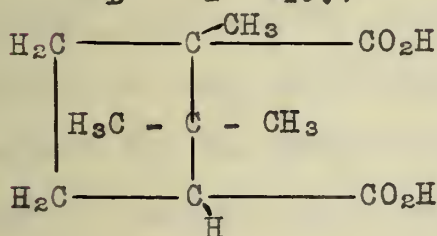
l-Isocamphoric Acid  
M.P. =  $172^{\circ}$   
 $\alpha_D = -47.6^{\circ}$



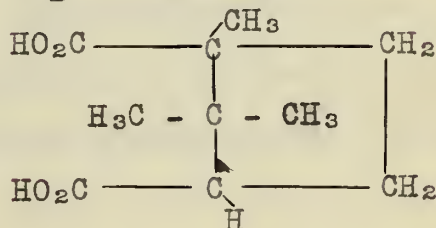
l-Camphoric Acid  
M.P. =  $187^{\circ}$   
 $\alpha_D = -49.7^{\circ}$



d-Isocamphoric Acid  
M.P. =  $171^{\circ}$ - $172^{\circ}$   
 $\alpha_D = +48.6^{\circ}$



<sup>1</sup>  
r-Camphoric Acid  
M.P. =  $202^{\circ}$  -  $203^{\circ}$   
 $\alpha_D = (\text{Inactive})$



<sup>1</sup>  
r-Isocamphoric Acid  
M.P. =  $191^{\circ}$   
 $\alpha_D = (\text{Inactive})$

#### THE METHYL ESTERS OF d-CAMPHORIC AND OF l-ISOCAMPHORIC ACID.

It will be noticed from the formulae given for the camphoric acids that one of the carboxyls is linked to a secondary, while the other is linked to a tertiary carbon atom. Substituents in the former position are designated by the prefix ortho or  $\alpha$  and these in the latter position by allo or  $\beta$ . In the present paper  $\alpha$  and

1. Ann., 127, 121; Compt. rend., 56, 698; Ber., 12, 1756; 105, 66  
29, 1700; Compt. rend., 108, 979; Ber., 27, 2001





$\beta$  will be used. The six methyl esters of d-camphoric and l-isocamphoric acid theoretically possible have been prepared.

|   | B.P.          | M.P.     | $\alpha_D$ |
|---|---------------|----------|------------|
| $\alpha, \beta$ -Methyl d-Camphorate <sup>1</sup> -----   | 155° (15 mm.) | (Liquid) | +48.16°    |
| $\alpha$ -Methyl d-Camphorate <sup>2</sup> -----          | 223° (21 mm.) | 77° -78° | +51.52°    |
| $\beta$ -Methyl d-Camphorate <sup>3</sup> -----           |               | 85° -86° | +43.55°    |
| $\alpha, \beta$ -Methyl l-Isocamphorate <sup>4</sup> ---- | 146° (27 mm.) | (Liquid) | -63.6°     |
| $\alpha$ -Methyl l-Isocamphorate <sup>5</sup> ----        |               | 88°      | -57.9°     |
| $\beta$ -Methyl l-Isocamphorate <sup>6</sup> ----         |               | (Liquid) | -53.1°     |

The speed of esterification for the secondary carboxyl is much greater than that for the tertiary. Thus the  $\alpha$  methyl esters may be prepared in good yield by boiling with methyl alcohol and sulphuric acid for about twenty minutes, while a good yield of the  $\alpha, \beta$  methyl esters is obtained only after boiling for several hours. Just as the  $\alpha$  carboxyl is the more easily esterified so it is the more easily saponified. Consequently by boiling with alkali for the proper length of time almost quantitative yields of the  $\beta$  methyl esters are obtained.

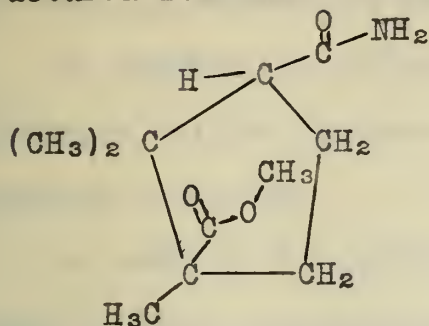
#### THE METHYL ESTERS OF d-CAMPHORAMIDIC AND l-ISOCAMPHORAMIDIC ACIDS

Each of the acid esters of d-camphoric and l-isocamphoric acid gives an amide ester by the action of ammonia on the acid chloride obtained by treating the ester with phosphorus pentachloride. Their

- 
1. Ber., 25, 1809; 25 (2), 665; Compt. rend., 114, 1517; J. Ch. Soc. 61, 1092; Monatsheft, 20, 687; Centr., 1908 (1), 424.
  2. Ann. (3) 38, 483; Ber., 25, 1807; 26, 285; Compt. rend., 114, 1516; 116, 148; J. Ch. Soc., 61, 1090; 77, 377; Monatsheft, 20, 686
  3. Compt. rend., 114, 1518; 141, 698; Ber., 25 (2), 665.
  4. J. Am. Ch. Soc., 32, 1671; 35, 77
  5. J. Am. Ch. Soc., 32, 1671; 35, 77
  6. J. Am. Ch. Soc., 35, 77

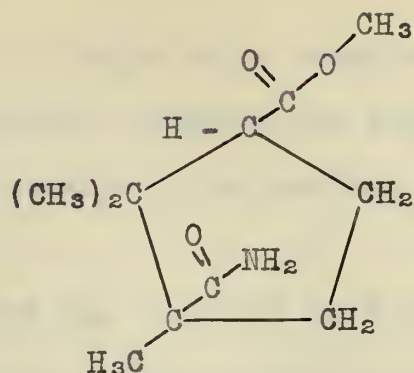


structural formulas follow:



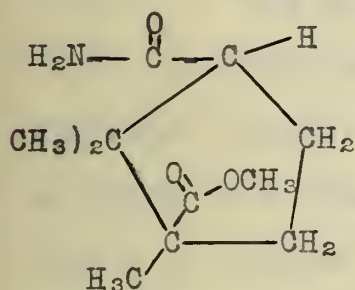
$\beta$ -Methyl  $\alpha$ -d-Camphoramidate

M.P. = 148°  
 $\alpha_D$  = +23.33



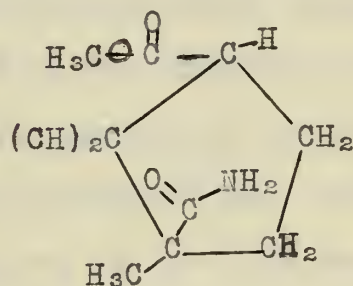
$\alpha$ -Methyl  $\beta$ -d-Camphoramidate

M.P. = 139°  
 $\alpha_D$  = +57.25



$\beta$ -Methyl  $\alpha$ -l-Isocamphoramidate

M.P. = 126 - 127°  
 $\alpha_D$  = -54.1



$\alpha$ -Methyl  $\beta$ -l-Isocamphoramidate

M.P. = 157°  
 $\alpha_D$  = -60.08

$\beta$ -METHYL  $\alpha$ -d-CAMPHORAMIDATE was first obtained by Van der Meulen<sup>1</sup> (1896), who obtained it by treating a methyl alcohol solution of cyanocamphonic<sup>3</sup> acid,  $C_8H_{14}-CO_2H$ , or of  $\alpha$ -Camphoric-isoimide,  $C_8H_{14}-C(=O)-N-H$ , with gaseous hydrogen chloride. Haller<sup>2</sup> (1895) also obtained it by the action of ammonia on  $\beta$ -methyl camphorate.

$\alpha$ -METHYL  $\beta$ -d-CAMPHORAMIDATE was prepared by Noyes<sup>4</sup> (1894) by the action of ammonia on  $\alpha$ -methyl  $\beta$ -d-camphoryl chloride. Van der Meulen<sup>1</sup> (1896) obtained it by the action of gaseous hydrogen chloride on a methyl alcohol solution of the free acid, or of  $\beta$ -camphor isoimide,  $C_8H_{14}-C(=O)-N-H$ . Haller<sup>2</sup> (1905) obtained it

1. Réoëuil, 15, 323.

2. Compt. rend., 141, 697

3. J. Am. Ch. Soc. 34, 1067 (1912)

4. Ber., 27, 918; Am. Ch. J., 16





by treating  $\alpha$ -methyl  $\beta$ -camphoryl chloride with ammonia.

$\beta$ -METHYL  $\alpha$ 1-ISOCAMPHORAMIDATE was prepared by Noyes and Littleton<sup>1</sup> (1913) by the action of ammonia on  $\alpha$ -methyl  $\beta$ -1-iso-camphoryl chloride.

$\alpha$ -METHYL  $\beta$ 1-ISOCAMPHORAMIDATE was prepared by Noyes and Knight<sup>2</sup> (1910) by treating  $\alpha$ -methyl  $\beta$ 1-isocamphorylchloride with ammonia.

#### THE d-CAMPHORAMIDIC AND 1-ISOCAMPHORAMIDIC ACIDS.

d-CAMPHORAMIDIC acid was prepared as the ammonium salt by Malaguti<sup>3</sup> (1837) by the action of gaseous ammonia on an alcoholic solution of d-camphoric anhydride. This substance was later identified by Laurent<sup>4</sup> (1846). It was prepared in the same manner by Ballo<sup>5</sup> (1879). Auwers and Schnell<sup>6</sup> (1893) obtained it by the action of aqueous instead of gaseous ammonia upon d-camphoric anhydride. It was obtained by Noyes<sup>7</sup> (1894), and by Hoogewerf and Van Dorp<sup>8</sup> (1895) in a similar manner. It has also been obtained by warming isonitroso camphor<sup>9</sup>,  $\text{C}_8\text{H}_{14}$   $\begin{array}{c} -\text{C} = \text{N}-\text{OH} \\ | \\ -\text{C} = \text{O} \end{array}$ , with fuming hydrochloric acid and by the decomposition of the chloroplatinate<sup>10</sup> of the hydrochloride of  $\alpha$ -camphornitrilic acid with water.

M. P.<sup>3</sup> = 176 - 177

$\alpha$  D = +45

1. J. Am. Ch. Soc., 35, 79

2. J. Am. Ch. Soc., 32, 1671

3. Ann., 22, 42

4. Ann., 60, 327

5. Ann., 197, 321.

6. Ber., 26, 1522.

7. Am. Ch. J., 16, 502; Ber., 27, 242.

8. Recueil, 14, 251

9. Ann., 274, 71; Ber., 26, 242.

10. Gazz. chim. ital., 26, (1), 416





$\beta$ -d-camphoramidic acid was first prepared by Noyes<sup>1</sup> (1894) by heating d-camphoric imide,  $C_8H_{14}$   $\begin{matrix} -C=O \\ | \\ NH \\ | \\ -C=O \end{matrix}$ , with 10 per cent sodium hydroxide solution. Hoogewerf and Van Dorp<sup>2</sup> (1895) prepared it by the same method and showed that it is formed in small amount with the  $\alpha$ -d-camphoramidic acid when an alcoholic solution of camphoric anhydride is treated with ammonia.

M.P.<sup>2</sup> =  $180^{\circ} - 181^{\circ}$ .  $\alpha_D^2 = +60^{\circ}$

$\beta$ , 1-ISOCAMPHORAMIDIC ACID was prepared by Noyes and Knight<sup>3</sup> (1910) by the saponification of  $\alpha$ -methyl  $\beta$ -1-isocamphoramidate.

M.P. =  $165^{\circ} - 166^{\circ}$ .  $\alpha_D =$

$\alpha$ , 1-ISOCAMPHORAMIDIC ACID HAS not been prepared.

#### THE AMINO ACIDS WHICH ARE DERIVED FROM THE d-CAMPHORAMIDIC AND 1-ISOCAMPHORAMIDIC ACIDS.

These acids have been prepared from the corresponding acid amides by Hofmann's reaction.

AMINOCAMPNONANIC ACID<sup>4</sup> (AMINOLAURONIC) is derived from  $\alpha$ -camphoramidic acid. It forms an anhydride which yields a nitroso derivative with nitrous acid. M.P.  $260^{\circ}$   $\alpha_D = -29.1^{\circ}$  Hydrochloride, M.P. =  $303^{\circ} - 305^{\circ}$   $\alpha_D = +24.9^{\circ}$ .

DIHYDROAMINOCAMPHOLYTIC ACID<sup>5</sup> is derived from  $\beta$ -camphoramidic acid. It forms an anhydride which yields a nitroso derivative with nitrous acid. M.P. = (Sublimes).  $\alpha_D = +54.5$  Hydrochloride, M.P. =  $261^{\circ} - 262^{\circ}$   $\alpha_D = +44.5^{\circ}$

1. Am. Ch. J., 16, 502; Ber., 27, 918

2. Recueil, 14, 251

3. J. Am. Ch. Soc., 32, 1671.

4. Am. Ch. J., 16, 503; 17, 432; 18, 3; Ber., 33, 2963; J.Ch. Soc., 99, 1270

5. Am. Ch. J. 16, 503; 16, 310; 17, 421; 24, 290.





ISOAMINOCAMPHONANIC (ISOAMINOLAURONIC) ACID<sup>1</sup> is derived from 1-isocamphoramidic acid. No anhydride has been prepared. Hydrochloride, M. P. =  $320^{\circ}$  (cor.).

ISODIHYDROAMINOCAMPHOLYTIC ACID<sup>2</sup> is derived from  $\beta$ ,1-isocamphoramidic acid. By boiling with acetic anhydride it yields the anhydride of dihydroaminocampholytic acid. M.P. =  $235^{\circ}$  -  $236^{\circ}$  (decomp.)  $\alpha_D = -32.9^{\circ}$ . Hydrochloride, M.P. =  $296^{\circ}$  -  $298^{\circ}$ .  
 $\alpha_D = -45.0^{\circ}$ .

THE METHYL ESTERS OF THE AMINOACIDS WHICH ARE DERIVED FROM  
 THE METHYL ESTERS OR THE d-CAMPHORAMIDIC AND l-ISOCAM-  
 PHORAMIDIC ACIDS+

METHYL AMINOCAMPHONANATE has not been prepared.

METHYL DIHYDROAMINOCAMPHOLYTATE has been prepared by Noyes<sup>3</sup> (1894). It is an oily liquid. The hydrochloride melts at  $244^{\circ}$ .

METHYL ISOAMINOCAMPHONANATE has been prepared by Noyes and Littleton<sup>4</sup> (1912). It boils at  $239^{\circ}$  (cor.). The hydrochloride melts at  $177^{\circ}$ , and has a rotation of,  $\alpha_D = -42.03$  (in alcohol);  $-32.03$  (in water.)

METHYL ISODIHYDROAMINOCAMPHOLYTATE has not been prepared.

THE DECOMPOSITION PRODUCTS OF AMINOCAMPHONANIC ACID.<sup>5</sup>

Noyes and Taveau<sup>6</sup> by decomposing this acid with nitrous acid or the nitroso derivative of the anhydride with alkali obtained the following products:

- 
1. J. Am. Ch. Soc., 35, 79.
  2. J. Am. Ch. Soc., 32, 1671
  3. Am. Ch. J., 16, 308
  4. J. Am. Ch. Soc., 35, 80
  5. Am. Ch. J., 16, 508; 17, 432; 32, 288; 35, 379.
  6. Am. Ch. J., 32, 288; 35, 379





## I. VOLATILE WITH STEAM.

1. A HYDROCARBON  $C_8H_{14}$  -----B.P. =  $122^{\circ}$  (27.8%)
2. ISOCAMPHOLACTONE  $C_8H_{14}$   $\begin{array}{c} \diagup C \\ \diagdown O \end{array}$  = 0 --M.P. =  $32^{\circ}$   
 $\alpha_D = -60.7^{\circ}$  (21.4%)
3. AN UNSATURATED ACID -----B.P. = 130-133/21mm.  
M.P. =  $152^{\circ}$ - $154^{\circ}$  (6.6%)
4.  $\gamma$ -LAURONOLIC ACID<sup>1</sup> (1.4%)

## II. NOT VOLATILE WITH STEAM.

1. HYDROXYLAURONIC ACID  $C_8H_{14}$   $\begin{array}{c} \diagup OH \\ \diagdown CO_2H \end{array}$  B.P. =  $180^{\circ}$ - $185^{\circ}$ /21mm.  
(1.7%)
2. A NEW LACTONE\*,  $C_8H_{14}$   $\begin{array}{c} \diagup C=O \\ \diagdown O \end{array}$  -----B.P. =  $126^{\circ}$ /27mm  
M.P. = 164 -165 (4.0%)

The above percentages are referred to the weight of the nitroso compound.

THE HYDROCARBON has been identified by Noyes and Derick<sup>2</sup> as laurolene. The laurolene formed by the decomposition of the amino acid with nitrous acid is dextro rotatory,  $\alpha_D^{23} = +22.8^{\circ}$ , and that obtained by the decomposition of the nitroso derivative with alkali is laevorotatory,  $\alpha_D = -14.5^{\circ}$ . The accepted formula for laurolene was proposed by Eijkman<sup>3</sup> from a study of its optical properties. Noyes and Kryiakides<sup>4</sup> later synthesized a hydrocarbon whose properties were identical with that of laurolene.

ISOCAMPHOLACTONE<sup>5</sup> by hydrolysis gives a hydroxy acid, the silver salt and methyl ether<sup>6</sup> of which have been prepared. Its structure is not yet known.<sup>7</sup>

\*-(It evidently remained behind as the hydroxy acid)-----

1. J. Ch. Soc., 67, 341.

2. J. Am. Ch. Soc., 31, 670

3. Chem. Weekblad, 1906, No. 15; 1907, No. 4; Centralb. 1907, II 1208

4. J. Am. Ch. Soc., 32, 1064

5. Am. Ch. J., 32, 290

6. Am. Ch. J., 35, 381

7. Ber., 35, 1292; J. Am. Ch. Soc., 31, 280



THE UNSATURATED ACID melting at  $152^{\circ}$  -  $154^{\circ}$  has not yet been investigated. 10

$\gamma$ -LAURONOLIC ACID<sup>1</sup> gives campholactone on standing with dilute sulphuric acid. It has never been obtained except as a viscous liquid and is probably a mixture of several isomeric acids.

HYDROXYLAURONIC ACID<sup>2</sup> has been obtained only as a viscous liquid.

THE NEW LACTONE has later<sup>3</sup> been shown to be identical with ciscamphonololactone which Bredt<sup>4</sup> prepared by the electrolytic reduction of camphononic acid. The pure lactone melts at  $165^{\circ}$  -  $167^{\circ}$  and has a specific rotation of  $\alpha_D = -22.3$ . The corresponding hydroxy acid is cis-camphonolic acid which has a specific rotation of  $\alpha_D = +29.2$ , and melts at  $202^{\circ}$  -  $203^{\circ}$ , depending upon the rate of heating. Noyes and Taveau give the melting point of their hydroxy acid as  $189.5^{\circ}$ . The hydroxyl and carboxyl of cis-camphonolic acid are in the  $\alpha$  and  $\beta$  positions respectively.

#### THE DECOMPOSITION PRODUCTS OF DIHYDROAMINOCAMPHOLYTIC ACID.<sup>5</sup>

The decomposition products of dihydroaminocampholytic acid have been studied by Noyes and Potter<sup>6</sup> (1912). The compounds formed are the following:

ISOLAUROLENE-----B.P. =  $106^{\circ}$  -  $110^{\circ}$   
1-CAMPHOLYTIC ACID----- $\alpha_D = -70.0^{\circ}$   
d-CAMPHOLYTOLACTONE-----M.P. =  $118-119^{\circ}$ ;  $\alpha_D = +8.5^{\circ}$   
d-TRANS-DIHYDROHYDROXYCAMPHOLYTIC ACID-M.P. =  $133.7^{\circ}$ ;  $\alpha_D = +70.1^{\circ}$

1. J. Ch. Soc., 67, 341; J. Am. Ch. Soc., 34, 176; Am. Ch. J., 17, 434

2. J. Am. Ch. Soc., 31, 280

3. J. Am. Soc., 34, 64

4. Ann., 366, 1.

5. Am. Ch. J., 16, 311; 17, 424; 24, 290; Ber., 33, 2938

6. J. Am. Ch. Soc., 34, 1067





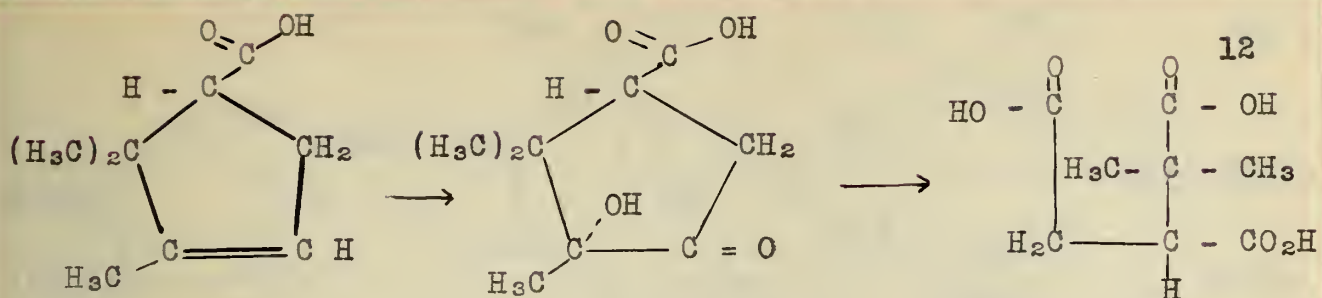


ISOLAUROLENE is optically inactive. Blanc<sup>1</sup> (1898) first proposed its correct structural formula, later (1906) establishing it by synthesis<sup>2</sup>.

1-CAMPHOLYTIC ACID was first prepared by Walker<sup>3</sup> (1893) by the electrolysis of the sodium salt of  $\alpha$ -ethyl d-camphorate, and saponification of the resulting ester.  $\alpha_D = -50^\circ$ . B. P. =  $240^\circ - 242^\circ$ . Noyes<sup>4</sup> (1894) prepared it by decomposing dihydroaminocampholytic acid. He showed<sup>5</sup> that upon standing with mineral acids it is changed to isocampholytic acid. Tiemann<sup>6</sup> prepared it in the same way. Noyes and Phillips<sup>7</sup> (1900) found the specific rotation to be  $\alpha_D = -60.4$ , and showed that distillation tends to racemize it. Noyes and Potter<sup>8</sup> found the rotation to be,  $-70.0^\circ$ . Racemic campholytic acid has been prepared by the action of hydrogen bromide on isocampholytic acid<sup>9</sup>, and by the reduction of  $\beta$ -campholytic acid<sup>10</sup>. Perkin and Thorpe<sup>11</sup> (1903) have synthesized the race-mic acid. It boils at  $127 - 128/14$  mm., and melts at  $31$ . Tiemann<sup>12</sup> (1900) and Blanc<sup>13</sup> (1901) have further demonstrated its structure by oxidation. Thus;-

- 
1. Bull, (3)19, 699
  2. Compt. rend., 142, 1084
  3. J.Ch. Soc., 63, 498
  4. Am. Ch. L. Soc., 16, 505
  5. Am. Ch. J., 17, 428
  6. Ber., 33, 2938
  7. Am. Ch. J., 24, 290
  8. J. Am. Ch. Soc., 24, 1077
  9. J.Ch. Soc., 77, 380; Am.Ch.J., 26, 285; Bull. (3) 25, 81
  10. J.Ch.Soc., 83, 853
  11. J. Ch. Soc., 85, 147; Chem. Centr., 1903 (1), 923; 1904 (1), 727
  12. Ber., 33, 2939
  13. Bull., (3) 25, 81



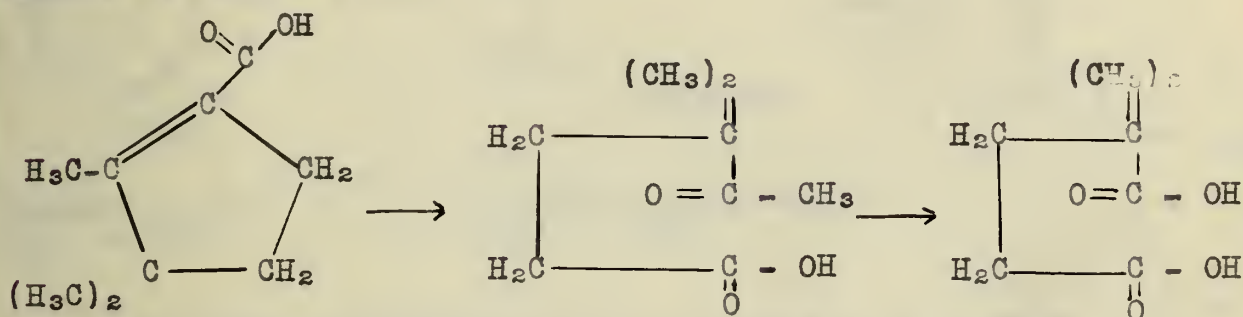


Campholytic Acid

M. P. =  $192^{\circ}$

Di-methyl Tricarballic Acid  
M.P. =  $156^{\circ}$  -  $157^{\circ}$

The structure of isocampholytic acid was shown in a similar manner by Blanc<sup>1</sup> (1899).



Isocampholytic Acid  
( $\beta$ -campholytic)  
(Isolauronolic Acid)

M.P. =  $132^{\circ}$

$\alpha_D$  = (inactive)

3,3-Di-methyl, 4-Keto,  
Hexanoic Acid

M.P. =  $48^{\circ}$

Di-methyl  
Glutaric Acid

M.P. =  $84^{\circ}$  -  $85^{\circ}$

Koinigs and Meyer (1894) had previously determined the structure of this acid by oxidation with potassium permanganate<sup>2</sup>. The isolauronic acid thus obtained gives by oxidation with sodium hypobromite  $\alpha, \alpha$ -dimethyl  $\alpha$ -carboxy adipic acid, which under the influence of heat loses carbon dioxide, giving  $\alpha, \alpha$ -dimethyl adipic acid. By heating with concentrated sulphuric acid it is converted into paraxylic acid, which drystallizes in short needles<sup>3</sup>. These reactions may be represented as follows:

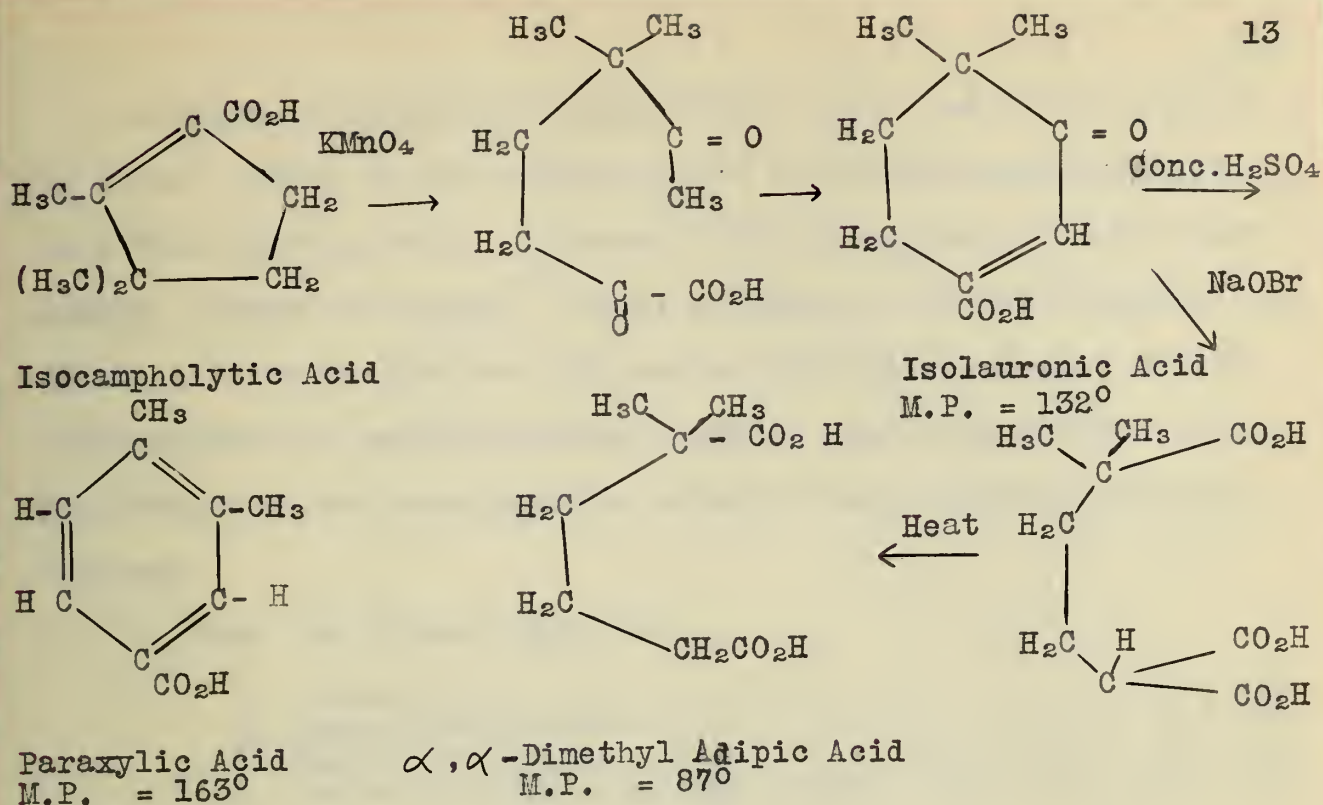
1. Ann. (7) 18, 252

2. Ber., 27, 3467

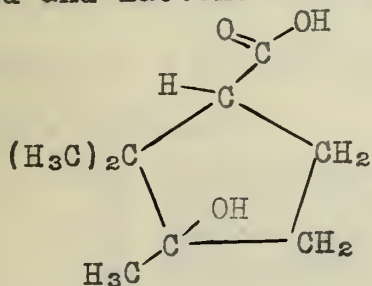
3. J.Ch.Soc., 71, 167



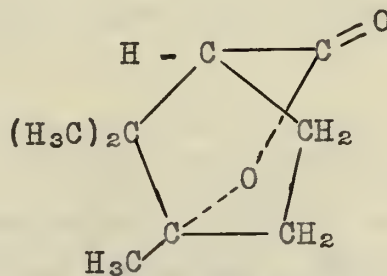




<sup>1</sup>  
 d-CAMPHOLYTOLACTONE was first obtained by Tiemann (1900) by decomposing dihydroaminocampholytic acid with nitrous acid. Blanc<sup>2</sup> (1901) found that some campholytolactone was formed in the preparation of r-campholytic acid from isocampholytic acid with hydrogen bromide. Noyes and Potter<sup>3</sup> (1912) prepared it by decomposing the nitroso derivative of dihydroaminocampholytic acid. They regard the corresponding hydroxy acid as a cis compound. The formula of the acid and lactone follow:



d-cis-dihydrohydroxycampholytic Acid  
 (Campholytolic)  
 M.P. = 118.5°  
 $\alpha_D = +56.8^\circ$



d-Campholytolactone  
 M.P. = 118° - 119°  
 $\alpha_D = +8.5^\circ$

1. Ber. 33, 2938  
 2. Bull., (3) 25, 81  
 3. J. Am. Ch. Soc., 34, 1075



d-TRANS-DIHYDROHYDROXYCAMPHOLYTIC ACID was first prepared by Noyes<sup>1</sup> (1895) in the decomposition of dihydroaminocampholytic acid with nitrous acid. Tiemann<sup>2</sup> (1800) prepared it in the same manner. Noyes and Potter<sup>3</sup> (1912) obtained it by the decomposition of the nitroso derivative with sodium hydroxide and also by the decomposition of aminodihydrocampholytic acid with nitrous acid. The yields of the decomposition products were approximately as follows:

I. From the Nitroso Compound.

|  |          |
|--|----------|
| 1. Isolaureolene-----                        | 3.0 o/o  |
| 2. Campholytolactone-----                    | 4.0 o/o  |
| 3. Campholytic Acid-----                     | 7.0 o/o  |
| 4. Trans-Dihydrohydroxycampholytic Acid----- | 45.0 o/o |

II. From the Amino Acid.

|  |          |
|--|----------|
| 1. Isolaureolene-----                        | 0.7 o/o  |
| 2. Campholytolactone-----                    | 5.3 o/o  |
| 3. Campholytic acid-----                     | 2.0 o/o  |
| 4. Trans-hydroxydihydrocampholytic Acid----- | 45.0 o/o |

They have shown that it has a trans configuration, since it does not form a lactone when heated by itself or with water. By warming or allowing to stand over night with dilute sulphuric acid, isocampholytic acid is formed. Bredt<sup>4</sup> (1900) obtained the lactone however by continued heating with acetic anhydride. By heating with water in a sealed tube on the steam bath the following products are obtained:

|  |          |
|--|----------|
| 1. Isolaureolene-----                        | 12.0 o/o |
| 2. Campholytolactone-----                    | 7.0 o/o  |
| 3. Campholytic Acid-----                     | 35.0 o/o |
| 4. Trans-Dihydrohydroxycampholytic Acid----- | 35.0 o/o |

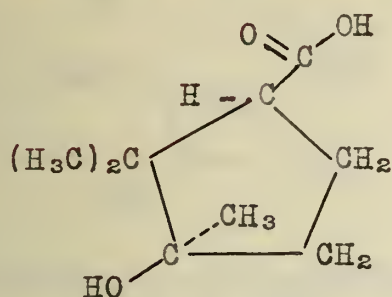
It is probably formed by a Walden inversion. The structure

1. Am. Ch. J., 17, 424.  
 2. Ber., 33, 2938  
 3. J. Am. Ch. Soc., 34, 1074  
 4. Ann., 314, 392



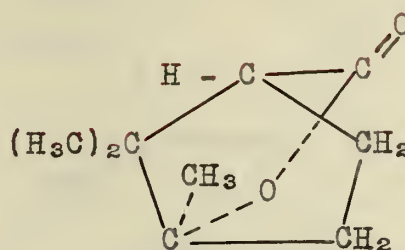


of the acid and lactone are as follows:



d-Trans-Dihydrohydroxycampholytic Acid

M.P. =  $133.7^{\circ}$   
 $\alpha_D = +70.1^{\circ}$



Lactone of d-Trans -Di-hydrohydroxycampholytic Acid

M.P. =  $115^{\circ} - 117^{\circ}$   
 $\alpha_D = +121.9^{\circ}$

#### THE DECOMPOSITION OF ISOAMINOCAMPHONANIC ACID.

Noyes and Littleton<sup>1</sup> (1913) decomposed this acid with nitrous acid obtaining the following products:

1. CIS-CAMPHONOLACTONE----M.P. =  $160^{\circ} - 162^{\circ}$ ;  $\alpha_D = -16.1^{\circ}$
2. AN UNSATURATED ACID-----B.P. =  $150^{\circ}/60$  mm.
3. A DARK VISCOUS OIL----- (Decomposes at  $160^{\circ}$ )

#### THE DECOMPOSITION OF ISODIHYDROAMINOCAMPHOLYTIC ACID.

Noyes and Knight decomposed<sup>2</sup> (1910) this acid with nitrous acid and obtained the following products:

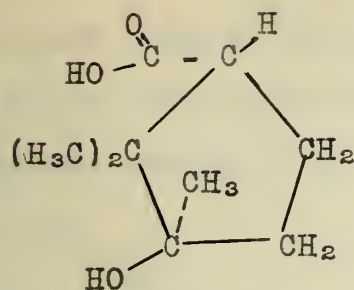
1. 1-DIHYDROHYDROXYCAMPHOLYTIC ACID-----
2. AN UNSATURATED ACID, (Probably d-campholytic)  $\alpha_D = +46.0^{\circ}$
3. A LACTONE-----
4. A HYDROCARBON-----

Noyes and Nickell<sup>3</sup> continued the investigation and obtained the following:

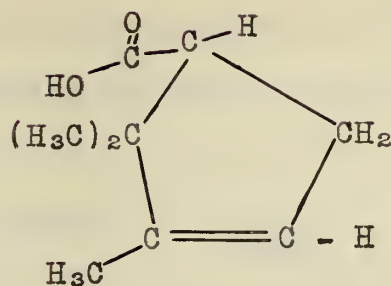
1. AN HYDROXY ACID-----M.P. =  $132^{\circ}$
2. d-CAMPHOLYTIC ACID-----B.P. =
3. 1-CAMPHOLYTOLACTONE-----M.P. =  $114^{\circ} - 115^{\circ}$ ;  $\alpha_D = -8.2^{\circ}$   
 B.P. =  $228^{\circ} - 230^{\circ}$
4. A SMALL AMOUNT OF A HYDROCARBON (Probably isolaurolene)

1. J.Am. Ch. Soc., 32, 1672.
2. J.Am. Ch. Soc., 32, 1669
3. J.Am. Ch. Soc., 36, 118

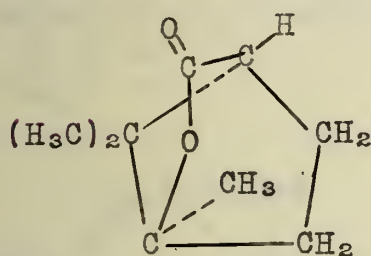




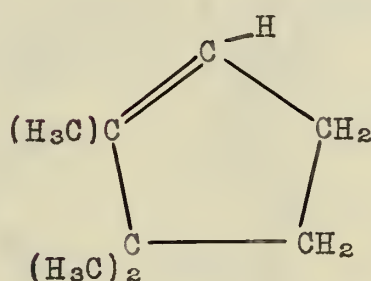
1 -cis-Dihydrohydroxycampholytic Acid<sup>1</sup>  
 M. P. = 132°  
 $\alpha_D = -70.04^\circ$



d-Campholytic Acid<sup>2</sup>  
 B.P. =  
 $\alpha_D = +66.35^\circ$



1-Campholytolactone<sup>2</sup>  
 C. P. = 228° - 230°  
 M. P. = 114° - 115°  
 $\alpha_D = -8.2^\circ$



Isolaurolene  
 B. P. = 108° - 110°  
 $\alpha_D = (\text{Inactive})$

The structure of the lactone<sup>2</sup> was established by converting it into 1-cis-dihydrohydroxycampholytic acid, which has a specific rotation of  $\alpha_D = -53.10$  and melts at 117° - 118°.

It is thus clear that the compounds formed in the decomposition of the four amino acids in question fall into the following four classes:

1. UNSATURATED ACIDS
2. HYDROXY ACIDS
3. HYDROCARBONS
4. LACTONES

#### THE UNSATURATED ACIDS

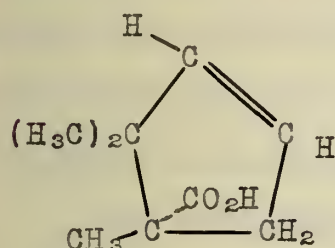
Thirteen unsaturated acids of the general formula  $C_8H_{13}CO_2H$ ,

1. J. Am. Ch. Soc., 32, 1669  
 2. J. Am. Ch. Soc., 36, 118





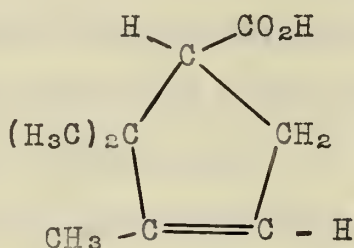
which are derived from the camphoric acids as shown in the preceding pages, have been prepared. Of this number the structure of eight are known.



Dehydrolauronic Acid<sup>1</sup>

M. P. =

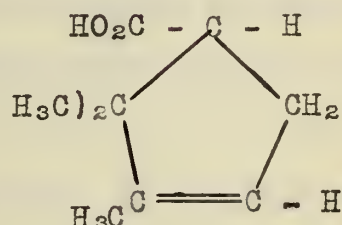
$\alpha_D$  =



1- $\alpha$  Campholytic Acid<sup>2</sup>

B. P. = 240°-243°

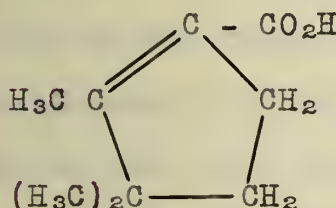
$\alpha_D$  = -70°



d- $\beta$  Campholytic Acid<sup>3</sup>

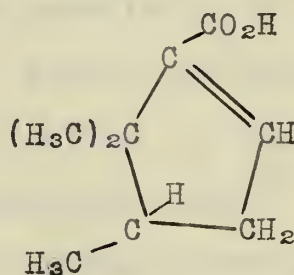
B. P. =

$\alpha_D$  = +66.36°

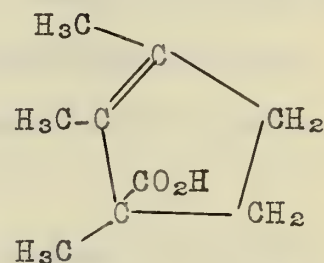


Isocampholytic Acid<sup>4</sup>

M. P. = 132°



$\Delta^5$ -Acid<sup>5</sup>

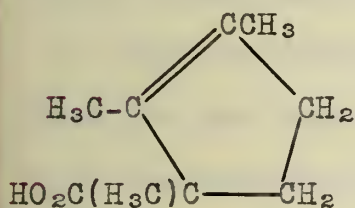


Lauronolic Acid<sup>6</sup>

M.P. = 6.5° - 8°

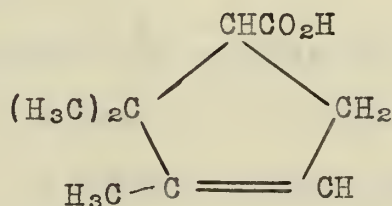
B.P. = 230°-235°

$\alpha_D$  = +187.7°



i-Lauronolic Acid<sup>7</sup>

M. P. = 5.8°



i-Campholytic Acid<sup>8</sup>

M. P. = 31°

B. P. = 127°-128°(14mm.)

1. Ber., 35, 1286

2. This Thesis, Page 11

3. This Thesis, Page 16

4. This Thesis, Page 12

5. Am. Ch. J., 26, 289; 22, 268

6. Ann., 227, 6; Ber., 27, 3504; 33, 3944; 33, 2944; J. Ch. Soc., 77, 1057; 79, 1289; Am. Ch. J., 16, 508; 17, 433; J. Ch. Soc., 67, 337

7. J. Am. Ch. Soc., 34, 181

8. Am. Ch. J., 26, 285; J. Ch. Soc., 77, 378.



Bredt<sup>1</sup> (1902) obtained dehydrolauronic acid by the dry distillation of the ester of dehydrocamphoric acid which he obtained by treating the diphenyl ester of chlorocamphoric acid with quinine. He called this compound lauronolic acid but gave no physical constants for it. The structure given rests upon the fact that it gives camphoronic acid on oxidation.

The structures of 1- $\alpha$ -campholytic acid and  $\beta$ -campholytic acid have been shown by methods previously described. The latter acid<sup>2</sup> is formed by treating  $\alpha$ -campholytic, dihydrohydroxycampholytic, campholytolic, infracampholenic, or i- $\alpha$ -campholytic acid with dilute mineral acids. Koenig and Hoerlin obtained it from sulphocamphylic acid. By treating its hydrobromide with alkalis it is converted into  $\alpha$ -campholytic acid.

The structure of d- $\alpha$ -campholytic acid is based upon its synthesis from isodihydrohydroxycampholytic acid and upon the fact that its optical rotation is practically equal and opposite to that of l- $\alpha$ -campholytic acid.

The structure<sup>3</sup> given the  $\Delta^5$  acid is the one most probable from its synthesis and also from the fact that it is not converted into isocampholytic acid by dilute mineral acids. Noyes and Blanchard (1901) obtained it by treating the  $\alpha$ -bromine derivative of a dihydrocampholytic acid with alcoholic potash. The dihydrocampholytic acid was prepared by the reduction of the hydroiodide of r- $\alpha$ -campholytic acid.

Lauronolic acid gives by oxidation no trace of camphoronic acid. By heating with soda-lime it gives laurolene which has been

1. Ber., 35, 1286

2. Am. Ch. J., 17, 428; 27, 432; 26, 285; Ber., 33, 2937; 33, 2939; 26, 813; J. Ch. Soc., 79, 108; 77, 378.

3. Am. Ch. J., 26, 289; 22, 268





shown to contain a 1,2,3 - trimethyl group. It has been prepared by treating aminocamphonanonic acid with nitrous acid or the nitroso derivative of the anhydride with sodium hydroxide, by the dry distillation of camphanic acid either alone or in a slow current of carbon dioxide, by the electrolysis of the sodium salt of the  $\beta$ -ethyl ester of camphoric acid, and by the action of sodium carbonate on bromcamphoric anhydride.

i-Launonic acid is formed by the distillation of i-camphanic acid which is derived from synthetic camphor.

Inactive campholytic acid has been prepared by the decomposition of the hydrobromide of  $\alpha$ -campholytic acid with sodium hydroxide. It has also been prepared from synthetic camphor<sup>1</sup> and is converted into  $\beta$ -campholytic acid by dilute mineral acids.

The  $\gamma$ -launonic acid<sup>2</sup> obtained by Noyes and Taveau is probably a mixture of optically active isomers of launonic acid. The structure of the unsaturated acid melting at  $152^{\circ}$  -  $154^{\circ}$ , which was obtained by Noyes and Taveau is unknown. The structure of the unsaturated acid obtained by Noyes and Littleton<sup>3</sup> also was not established.

#### THE HYDROXY ACIDS.

Of the nine hydroxy acids of this series that have been prepared the structures of seven are known, although the evidence for some of them is far from complete.

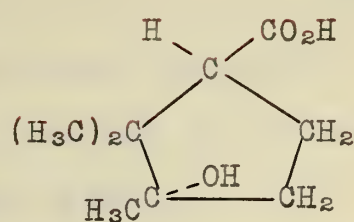
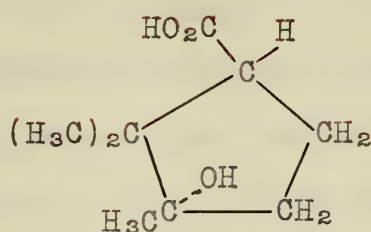
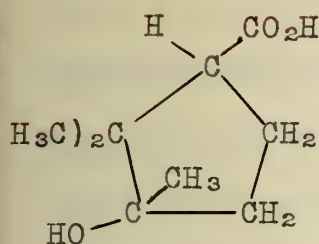
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1. Am. Ch. J., 27, 432.

2. Am. Ch. J., 32, 288.

3. J. Am. Ch. Soc., 35, 81.





Trans d-Dihydrohydroxy -  
campholytic Acid<sup>1</sup>

M. P. = 132° - 133°

$\alpha_D = +72.05^\circ$

Trans l-Dihydrohydroxy-  
campholytic Acid

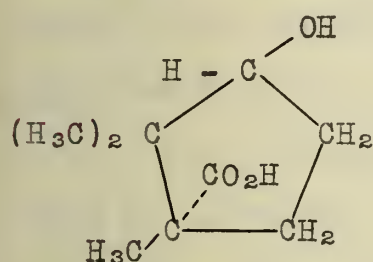
M. P. = 132°

$\alpha_D = 70.04^\circ$

Cis d-Dihydrohydroxy-  
campholytic Acid

M.P. = 121°

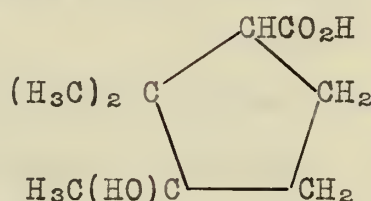
$\alpha_D = +50.8^\circ$



Cis Camphonolic Acid<sup>4</sup>

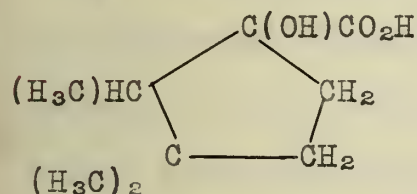
M. P. = 202° - 203°

$\alpha_D = +29.2^\circ$



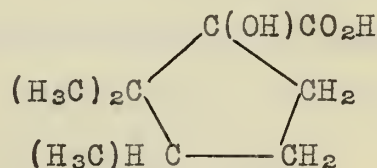
r-Dihydrohydroxycampholytic Acid

M. P. 173°



$\alpha$ -Hydroxy Dihydroisocampholytic  
Acid

M. P. = 112°



$\alpha$ -Hydroxy Dihydrocampholytic  
Acid

Noyes and Potter (1912) have demonstrated the structure<sup>1</sup> of trans-didihydrohydroxycampholytic acid. It does not readily form a lactone and upon oxidation does not form a ketonic acid. When heated with water at 100° it gives chiefly isolaurelene and campholytic acid with only a small amount of campholytolactone. The iso-

1. This Thesis, Page 10; J. Am. Ch. Soc., 34, 1069; Ber., 33, 2937

2. This Thesis, Page 15; J. Am. Ch. Soc., 32, 1673

3. J. Am. Ch. Soc., 34, 1069; Ber., 33, 2939

4. J. Am. Ch. Soc., 34, 66; Ann., 366, 2.





meric cis-d-dihydrohydroxycampholytic acid<sup>1</sup> readily gives campholytolactone by heating with water at 100° and does not give a ketonic acid by oxidation. Both acids are converted to  $\beta$ -campholytic acid by treatment with dilute sulphuric acid.

The structure<sup>2</sup> of trans-l-dihydrohydroxycampholytic acid follows shiefly from its synthesis. The rotation is practically equal and opposite to that of trans-d-dihydrohydroxycampholytic acid. When the two are mixed the melting point approaches that of the racemic acid.

The structure<sup>3</sup> of cis-camphonolic acid follows from the fact that it is formed by the reduction of camphononic acid. It gives cis-camphonololactone by heating at 255°, and is oxidized to camphononic acid by Beckmann's chromic acid mixture.

r-Dihydrohydroxycampholytic acid has been prepared by Noyes and Patterson<sup>4</sup> (1902) by treating the hydrobromide of  $\beta$ -campholytic acid with sodium hydroxide. They also obtained it by decomposing i-dihydroaminocampholytic acid with nitrous acid.

A hydroxy acid derived from isocampholactone has been prepared by Noyes and Taveau<sup>5</sup>. Hydroxylauronic acid<sup>6</sup> has been obtained from the decomposition of aminocamphononic acid with nitrous acid. Noyes and Shepherd<sup>7</sup> (1899) obtained  $\alpha$ -hydroxy dihydroisocampholytic acid by treating the ethyl ester of  $\alpha$ -brom-dihydro- $\beta$ -campholytic acid with barium hydroxide. Noyes and Patterson prepared

1. J. Am. C. Soc., 34, 1069; Ber., 33, 2939.

2. This Thesis, Page 15; J. Am. Ch. Soc., 32, 1673

3. J. Am. Ch. Soc., 34, 66; Ann., 366, 2.

4. Am. Ch. J., 26, 286; 27, 432

5. Am. Ch. J., 32, 290

6. This Thesis, Page 10.

7. Ber., 32, 2291

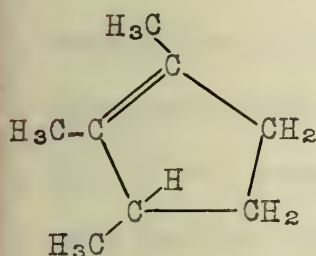
8. Am. Ch. J., 27, 427.



$\alpha$ -hydroxy dihydrocampholytic acid by treating  $\alpha$ -bromo dihydrocampholytic acid with barium hydroxide. The structures of the last two follow from the method of preparation.

### THE HYDROCARBONS.

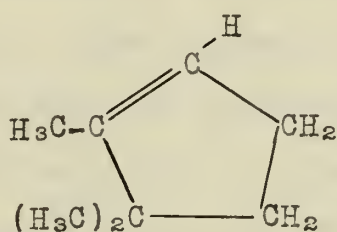
Three hydrocarbons having the general formula  $C_8H_{14}$ , which are derived from the camphoric acids, have been prepared.



Laurolene

B. P. =  $120^{\circ}$ - $122^{\circ}$

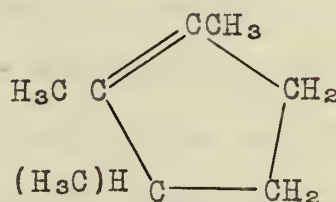
$\alpha_D = -29.2^{\circ}$  to  $+28.15^{\circ}$



Isolauroleone

B. P. =  $108^{\circ}$ - $110^{\circ}$

$\alpha_D = (\text{Inactive})$



r-Laurolene

B. P. =  $120^{\circ}$ - $121^{\circ}$

Laurolene has been obtained in the decomposition<sup>1</sup> of amino-camphonanic acid, by the distillation of calcium camphanate<sup>2</sup>, by the slow distillation of camphanic acid<sup>3</sup>, either alone or in a slow current of carbon dioxide, and by the distillation of lauronolic acid<sup>4</sup> with soda-lime or zinc chloride. Its optical rotation<sup>5</sup> varies according to the method of preparation. Its structure<sup>6</sup> is well established by synthesis and by the fact that it gives by oxidation with a cold dilute alkaline solution of potassium permanganate a straight chain diketone ( $CH_3 - \overset{O}{\parallel} C - CH_2 - CH_2 - \overset{CH_3}{\underset{O}{\parallel}} C - CH_3$ ) which is optically active.

1. This Thesis, Page 9.

2. Ber., 26, 1202; Ann., 163, 336.

3. Ann., 163, 336; 290, 185; 319, 311; 227, 5: J. Ch. Soc., 89, 27

4. J. Am. Ch. Soc., 34, 178

5. J. Am. Ch. Soc., 31, 670.

6. This Thesis, Page 9: J. Am. Ch. Soc., 31, 672.





<sup>1</sup>  
Eijkmann (1906) predicted, on the basis of refractometric studies, the constitution of lauroleone before it had been established by chemical methods. According to his view a ring structure in which one double bond is located is to be regarded as a single side chain while a compound (semicyclic) containing a double bond between two atoms only one of which is a member of the ring is to be regarded as two side chains. By calculating the dispersion from refractive indices by the three hydrogen lines for lauroleone and hydrolauroleone he found that the difference was exactly accounted for by the summation of the effects of one double union and three side chains, these values having been obtained by measurement of compounds of known structure. This makes it necessary that lauroleone contain the group  $\text{-C}^{\text{CH}_3} = \text{C}^{\text{CH}_3}$ , if his assumptions are correct.

The structure <sup>2</sup> of isolauroleone has been established by synthesis. It has been prepared by distilling copper camphorate <sup>3</sup> from sulfocamphylic <sup>4</sup> acid, and from the decomposition of  $\beta$ -campholytic acid <sup>5</sup>, dihydroaminocampholytic acid <sup>6</sup>, and dihydrohydroxycampholytic <sup>7</sup> acid.

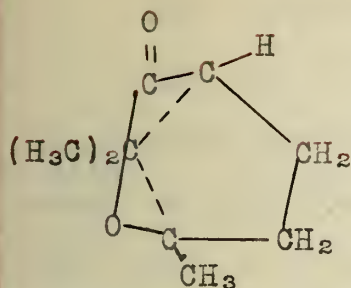
r-Lauroleone boils at  $120^\circ - 121^\circ$  (752 mm.)

#### THE LACTONES.

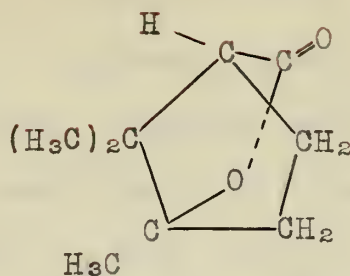
Eight lactones having the general formula  $\text{C}_8\text{H}_{14} - \text{C} = \text{O}$  have been prepared. Of this number the structures of three are fairly well known.

- 
1. Chem. Weekblad, 3, 708. Cf. also "Over de Synthese en Structuur van eenige Lauroleenderivaten," by J. L. Hoving. Pp. 29, 64
  2. This Thesis, Page 11.
  3. Jsb. Chem., (1866). 410.
  4. Ber., 20, 2957; 27, 3470.
  5. Bull. soc. chim., (3), 19, 703; Ann., 319, 307; J.Ch.Soc., 89, 29
  6. This thesis, page 10
  7. J. Am. Ch. Soc., 34, 1074

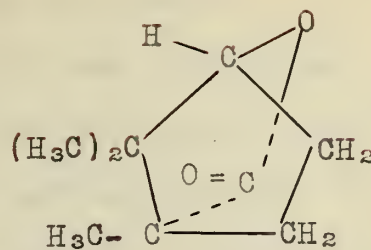




1-Campholytolactone  
M. P. = 228°-230°  
M. P. = 114°-115°



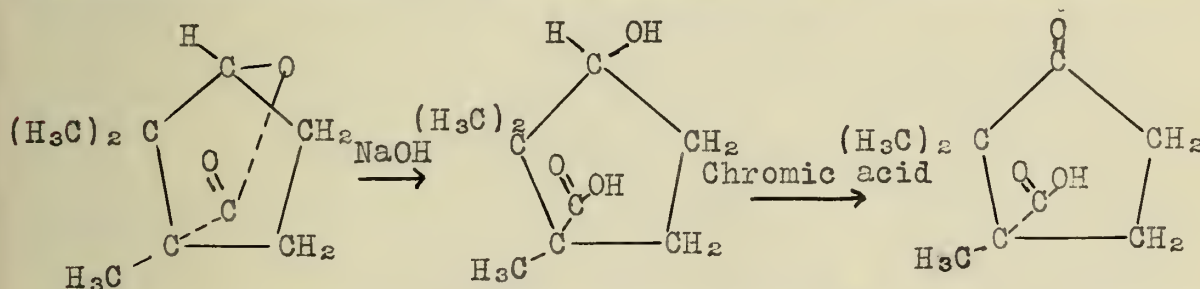
d-Campholytolactone  
M. P. = 118°-119°  
 $\alpha_D = +8.5^\circ$



Cis Camphonololactone  
M. P. = 165°-167°  
 $\alpha_D = -22.3^\circ$

The structure <sup>1</sup> of d-campholytolactone is based upon its conversion into d-cis-dihydrohydroxycampholytic acid by dilute alkali.

Noyes and Potter (1912) have demonstrated the structure of cis camphonololactone <sup>2</sup> by the following series of reactions:



The structure of l-campholytolactone <sup>3</sup> has been established by converting it into l-campholytic acid.

$\psi$ -campholactone was prepared by Lees and Perkin <sup>4</sup> by treating camphoric anhydride with aluminium chloride. It is a mixture for by treatment with barium hydroxide two hydroxy acids are formed, one melting at 113° and the other by 160°.

A lactone <sup>5</sup> has been obtained from dihydrohydroxycampholytic acid, which melted at 115° - 117° and had a specific rotation of  $\alpha_D = +121.9^\circ$ .

1. This Thesis, Page 10

2. This Thesis, Page 10; J. Am. Ch. Soc., 34, 66.

3. This Thesis, Page 15.

4. J. Ch. Soc., 79, 332.

5. This Thesis, Page 15.





1

The structure of isocampholactone<sup>1</sup> is not known.

The structure of campholactone has not been determined. It is prepared by distilling camphanic acid<sup>2</sup> and by warming lauronolic acid<sup>3</sup> at 100° for a short time with dilute sulphuric acid. M. P. = 49° - 50°.  $\alpha_D = -21.6^\circ$ . With barium hydroxide a hydroxy acid<sup>4</sup> is obtained which melts at 144° - 145° and has a rotation of  $\alpha_D = +16.0^\circ$ .

i- $\alpha$ -campholactone has been prepared by Perkin and Thorpe<sup>5</sup> (1904) from magnesium alkyl halide and ethyl ketodimethyl pentamethylene carboxylate. B. P. = 155° - 157° (50 mm.). It forms a hydroxy acid which is converted into  $\beta$ -campholytic acid by dilute mineral acids.

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1. This Thesis, Page 9.

2. Ann., 227, 10: Ber., 28, 2165: 27, 2114

3. J. Am. Ch. Soc., 34, 181.

4. Ann., 227, 11: Ber., 33, 2946

5. J. Ch. Soc., 85, 132.



## II THEORETICAL.

This investigation had for its purpose a study of the products obtained by decomposing isoaminocamphonanic acid with nitrous acid. After the work was begun, however, it was decided to decompose the methyl ester of the acid since the products would then be subject to fractional distillation under diminished pressure without danger of decomposition and rearrangement, the advantage being that in case more than one of each the unsaturated and hydroxy compounds were obtained a purely physical method of separation at once presented itself. In order to secure any efficient separation by such a method it will be at once apparent that it was necessary to work with very large quantities of materials.

As shown in the experimental part we have found that the methyl ester of isoaminocamphonanic acid by decomposition with nitrous acid gives the methyl ether and the methyl ester of cis-camphonolic acid, and the methyl esters of lauronolic acid, 1,2, 2 trimethyl 1-carboxy cyclopentene-2, a tertiary  $\beta$ -hydroxy acid, and a secondary  $\beta$ -hydroxy acid.

As indicated in the preceding pages the four amino acids derived from d-camphoric and l-Isocamphoric acids have been decomposed with nitrous acid. In these four cases one fact that stands out prominently is that the decomposition is the usual one for aliphatic amines. The second noticeable feature is that in each case intramolecular rearrangements have occurred. In the third place a larger number of products are obtained in the case of the amino acid containing an amine group on the secondary carbon atom. This latter fact is to be foreseen since the primary amine group





in this case is linked to a carbon bearing a hydrogen atom which is as a rule more mobile than the methyl group which is linked to the tertiary carbon atom bearing the amine group. This will be clear from an examination of the formulae on page 5.

As the diazonium group represents the seat of the change from the amine to the unsaturated and hydroxy compounds a resumé of our knowledge in regard to their structure will be presented at this point.

The diazo compounds were discovered in 1858 by Peter Griess,<sup>1</sup> who regarded them as derived from the hydrocarbons by replacement of two hydrogen atoms by two of nitrogen. Kekulé (1866) showed<sup>2</sup> that this was not the case since by replacement reactions a mono-substitution product always results. He suggested the diazo formula  $R - N = N - OH$ . Blomstrand<sup>3</sup> (1869), Strecker<sup>4</sup> (1871) and Erlenmeyer<sup>5</sup> (1874) independently suggested the diazonium formula  $R - \overset{OH}{N} \equiv N$ . Later v. Pechmann<sup>6</sup> (1892) suggested the nitrosamine formula  $R - \overset{H}{N} - N = O$  upon the bases of the reaction,

$$Ph - \overset{H}{N} - N = O + Cl - \overset{O}{C} - Ph \longrightarrow Ph - \overset{N}{\underset{\underset{O}{||}}{C}} - N = O + HCl$$

1. Ann., 106, 123: Ber., 39, 2762

2. Lehrb. d. org. Chem., II, 717

3. Ber., 8, 51

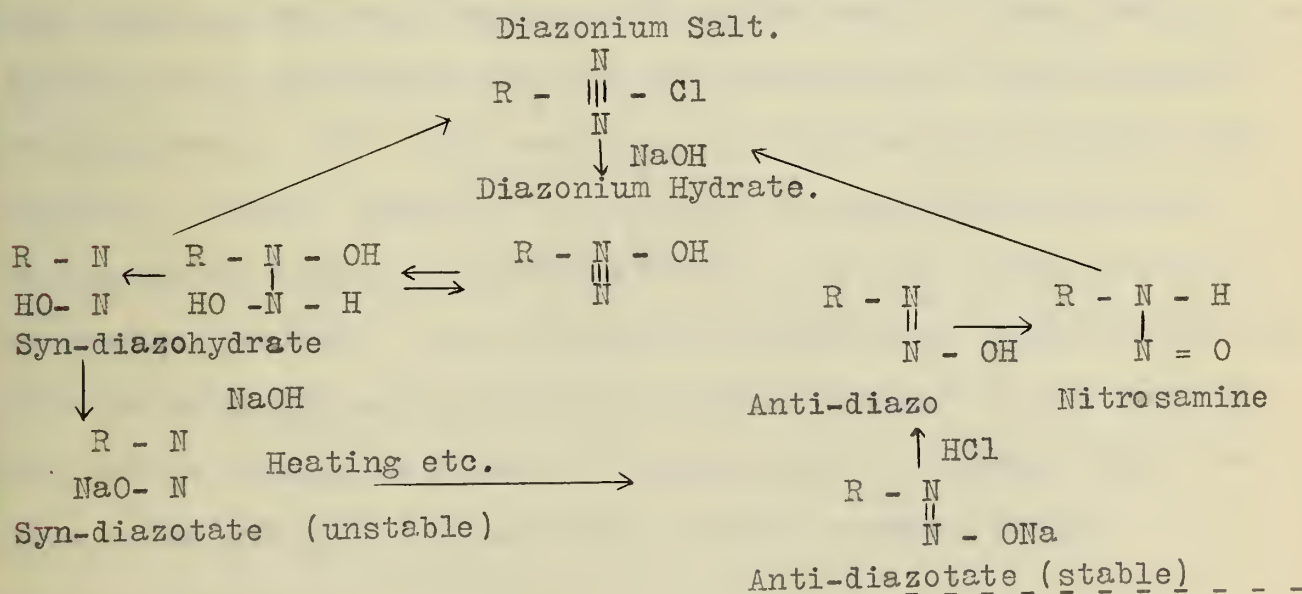
4. Ber., 4, 786.

5. Ber., 7, 1110

6. Ber., 25, 3505: 27, 651.



In 1864 isomeric diazo compounds were discovered independently by Schraube and Schmidt,<sup>1</sup> v. Pechmann and Frobenius<sup>2</sup>, and by Bamberger<sup>3</sup>. It was found that potassium diazobenzene possessed entirely the character of a diazo compound. If it is heated with concentrated KOH solution it no longer possesses the power of coupling, however, if then treated with an excess of acid the diazo character is again restored. Although the new isomer gave nitroso-methylamine with methyl iodide this could not at that time be considered proof of the nitrosamine structure, since it did not react with aceto-acetic ester and similar compounds to give hydrazones and, since its silver salt with methyl iodide gave the methyl ether of normal diazo benzene,  $\text{Ph} - \text{N} = \text{N} - \text{O} - \text{CH}_3$ . In the same year Hantzsch<sup>4</sup> suggested cis-trans isomerism as the explanation of the problem. Since that time a long controversy has ensued in which it has been shown that all four formulae are correct under certain conditions. Hantzsch has expressed these relationships as follows:



1. Ber., 27, 514  
 2. Ber., 27, 672  
 3. Ber., 27, 679  
 4. Ber., 27, 1702





If it is assumed that the nitrogen atom is situated at one corner of a regular tetrahedron and that the three valences are directed toward the other three corners, the models for the syn and anti-diazo compounds will be as follows:

Fig. I.

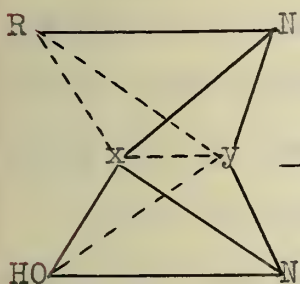
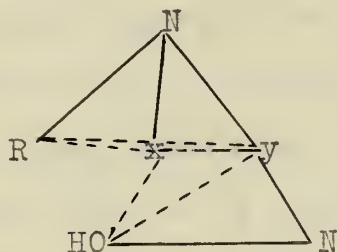
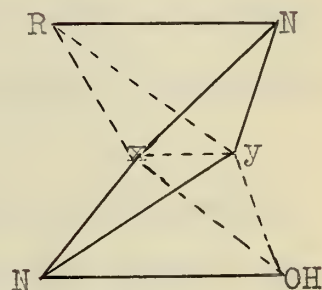


Fig. II.



Syn.

Fig. III



Anti

It will be noticed from a comparison of Figs. I & III that the syn compound is in a state of much greater strain, the line xy and the points N not being in the same plane in case of the syn compound. For this condition to be realized, R and OH must move toward each <sup>other</sup> (Fig. II). Experimentally it has been found that the syn compounds are much more readily formed and are less stable, the typical diazo decomposition into ROH and nitrogen being peculiar to this series. The anti compounds do this much less readily and require a higher temperature. They are in equilibrium with the corresponding diazonium hydrates which are strong bases, comparable to sodium hydroxide. The syn diazo compounds are feebly acidic and this explains why one form can be readily changed to the other by the action of acid or alkali. The anti diazo compounds behave as true acids and give various tests for the hydroxyl group.



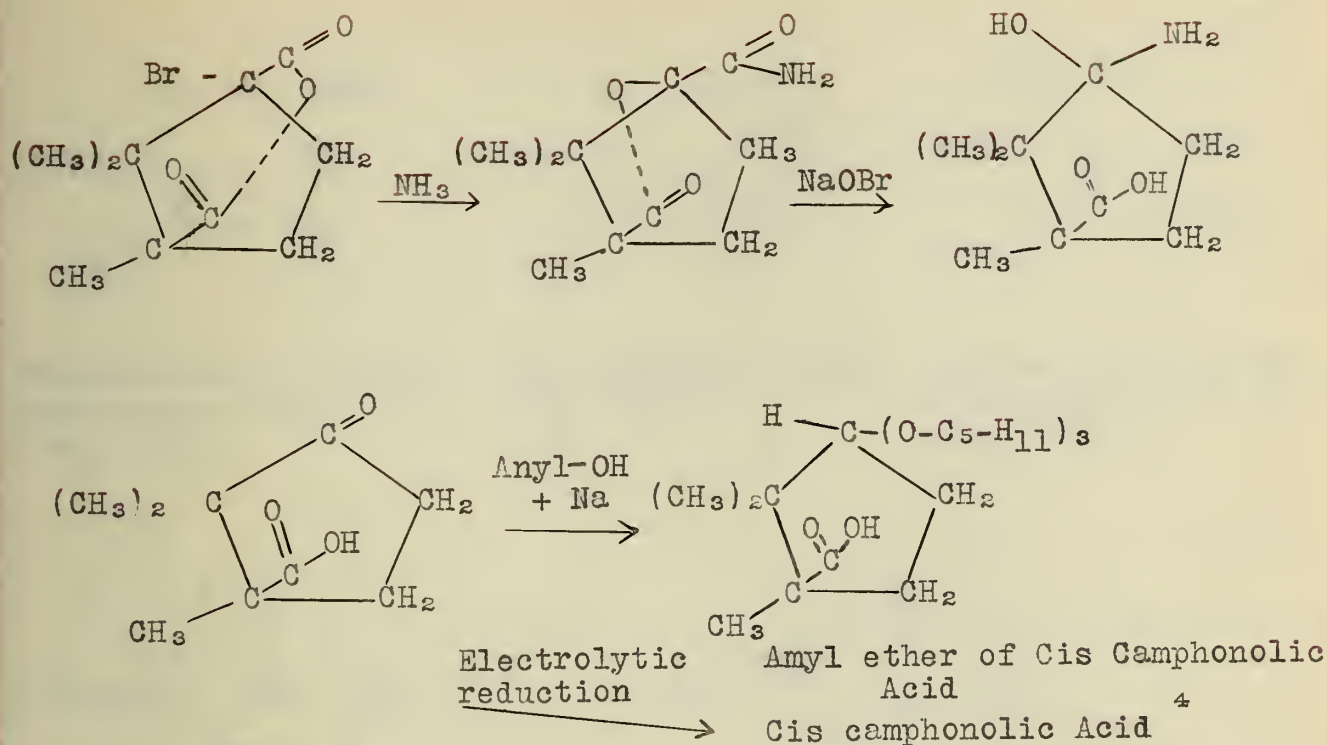
<sup>1</sup>  
Aschan has shown that d- and l-camphoric acids allow racemization of the secondary carboxyl, when sufficient strain is produced in the molecule by heat, so that where equilibrium is established fifty per cent l-isocamphoric or a like amount of d-isocamphoric acid results. With this in mind it is to be expected that in passing from an amine to a diazo compound the molecule would be subjected to considerable strain and it is not at all unlikely that racemization of the diazo group would take place.

This has indeed been found to be the case as both the methyl ester and the methyl ether of cis-camphonolic acid are formed. This acid has been oxidized to camphononic acid whose structure has been demonstrated by Lapworth and Lenton<sup>2</sup> (1901) Starting with Br-camphoric anhydride they prepared the amide of camphanic acid and from this by the Hofman hypobromite reaction the amino acid. Now if the hydroxyl and primary amine group are on the same carbon atom the compound should be unstable giving ammonia and camphononic acid. This has been found to be the case and is perhaps the best method of preparing camphononic acid. These changes may be represented as follows:

- 
1. Ber., 27, 2005
  2. J. Ch. Soc., 79, 1287.
  3. J. Am. Ch. Soc., 34, 65
  4. Ann., 366, 1.



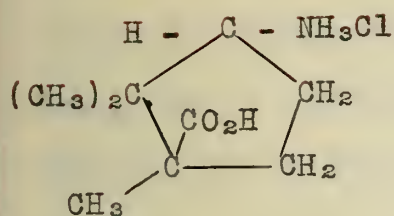




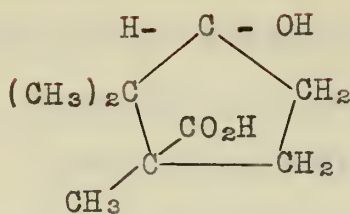
Furthermore the weight of evidence is in favor of the *cis* configuration. As such the acid should be considered as being derived from d-camphoric acid and should have a rotation comparable to the hydrochloride of aminocamphonanic acid, while that of the lactone should compare with the rotation of amino-camphonanic acid itself. There should also be no comparison between the rotations of the acid and the hydrochloride of isoaminocamphonanic acid. The agreement with fact is obvious. Another argument in favor of *cis* configuration is that the acid readily gives the lactone by heating alone, no dehydrating agent being necessary.

The formation of the methyl ether of *cis*-camphonolic acid under the conditions employed has no parallel in the literature so far as the writer is aware. If it is formed by the initial saponification of ester and subsequent action of methyl nitrite on *cis*-camphonolic acid, it is at once apparent that still other

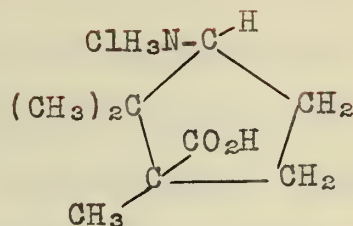




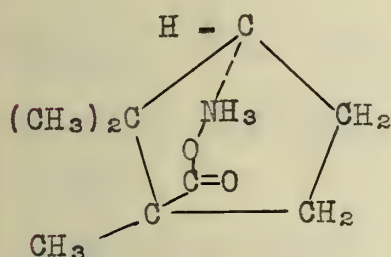
Hydrochloride of Amino-camphonanilic Acid  
 $\alpha_D = 25.0$



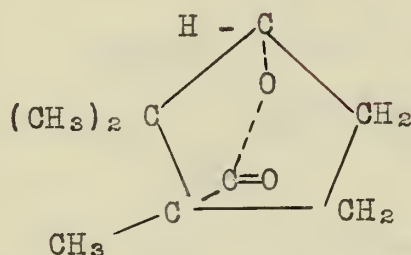
Cis-Camphonilic Acid  
 $\alpha_D = 29.7$



Hydrochloride of Iso-aminocamphonanilic Acid  
 $\alpha_D = -28.8$



Aminocamphonanilic Acid  
 $\alpha_D = -29.2$



Cis-Camphonolactone  
 $\alpha_D = -22.3$

free acids would result because the diazo group is decomposing simultaneously. The ether acid is the only one formed and therefore the change must be intramolecular, that is, the methyl group does not detach itself except as a free radical.

For the following reasons it is improbable that racemization of the syn compound as such will take place:

(1) In the light of the present knowledge regarding the diazo compounds it is the syn-diazo hydrate (See page 29), which is least stable, readily going over into the diazonium compound or anti-diazo hydrate, or finally decomposing with the loss of nitrogen.

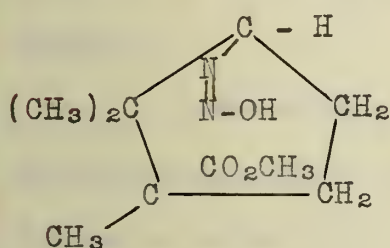
(2) If, in accordance with the usual explanation of racemiza-





tion, the hydrogen and syn diazo groups on the  $\alpha$  carbon exchange places by simple revolution in a horizontal orbit perpendicular to the plane of the ring, the process is a mechanical impossibility as will appear in Fig. I. On the other hand, if the exchange takes place by rotation in an orbit situated at right angles to the above, it is evident from Fig. II. that the trans syn-diazo compound will be changed to a cis anti-diazo compound.

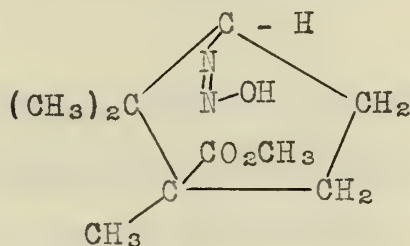
Fig. I



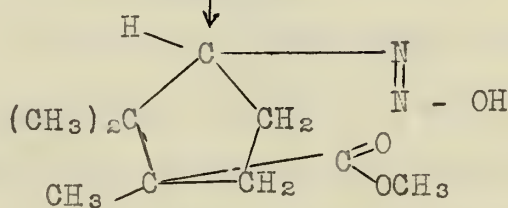
Trans syn-diazo

Decomposes as such or by rearrangement to the diazonium compound.

Fig. II.



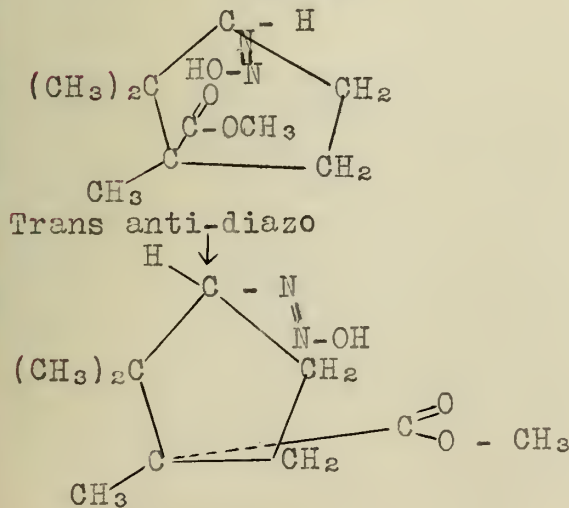
Trans Syn-diazo



Cis Anti-diazo

The anti compound may be expressed by Figs. III and IV

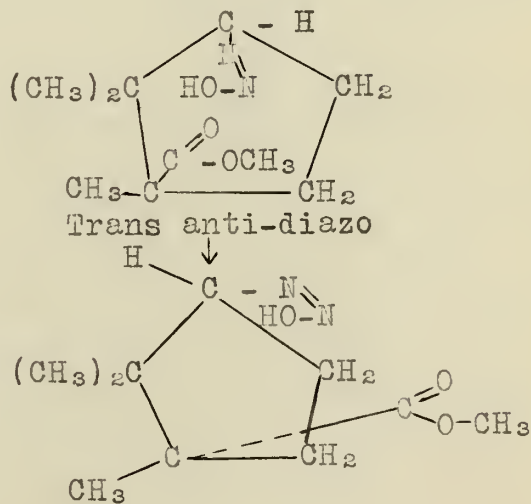
Fig. III



Trans anti-diazo

Cis Anti-diazo

Fig. IV



Trans anti-diazo

Cis syn-diazo



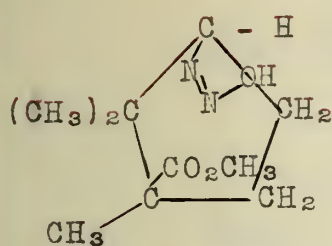
It has been pointed out in the preceding pages that the typical diazo decomposition is peculiar to the syn series and Hantzsch has shown that the true syn-diazo hydrates can not be isolated at all because of the ease with which they decompose and the readiness with which they rearrange into their more stable isomers, the diazonium hydrates and the anti-diazo-hydrates. Now since the aliphatic diazo compounds decompose spontaneously in acid solution, the inference is that it is the syn compound which is formed.

Furthermore the methyl esters of aminocamphonanic and aminodihydrocampholytic acid have been decomposed with nitrous acid. Since no ether acid is formed in either of these cases it is evident that the syn-diazo compound is not responsible for this peculiar transformation. It must then be due to the anti-diazo which is derived according to the scheme represented in Fig. II, page 10.

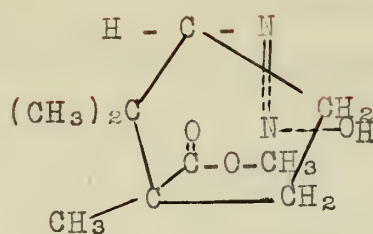
The following scheme is therefore given as the mechanism by which the methyl ether and the methyl ester of cis-camphonolic acid are formed:



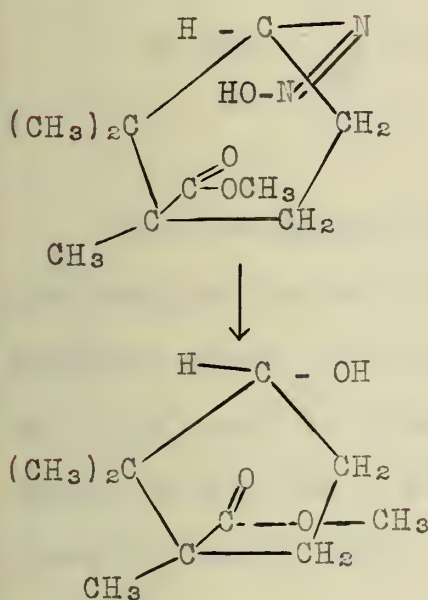
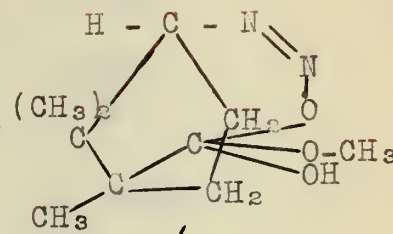




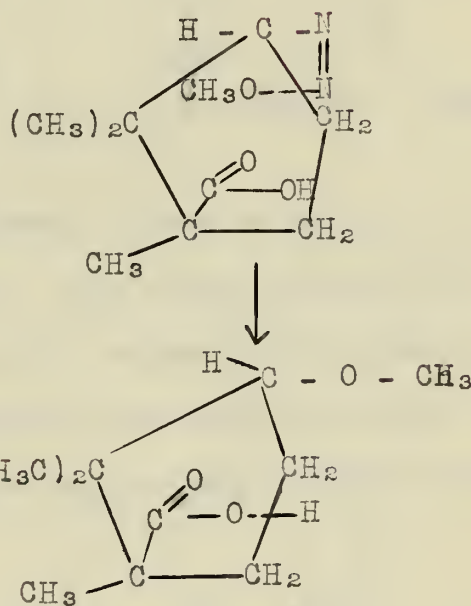
Trans-syn-diazo



Cis-anti diazo



Methyl Cis-camphonolate

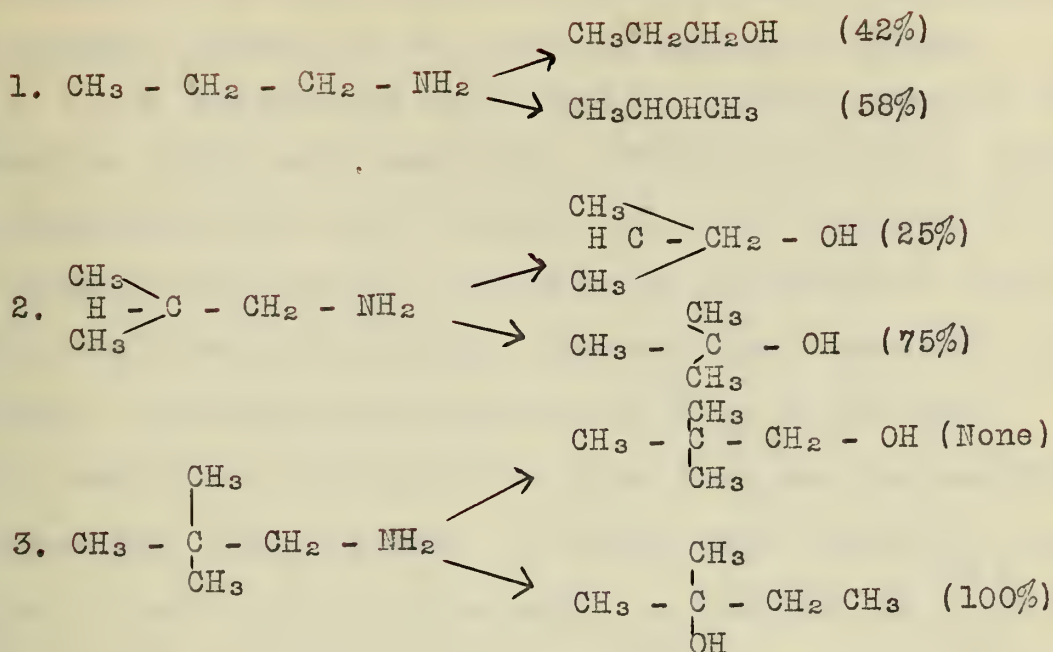


Methyl ether of Cis-camphonolic Acid.

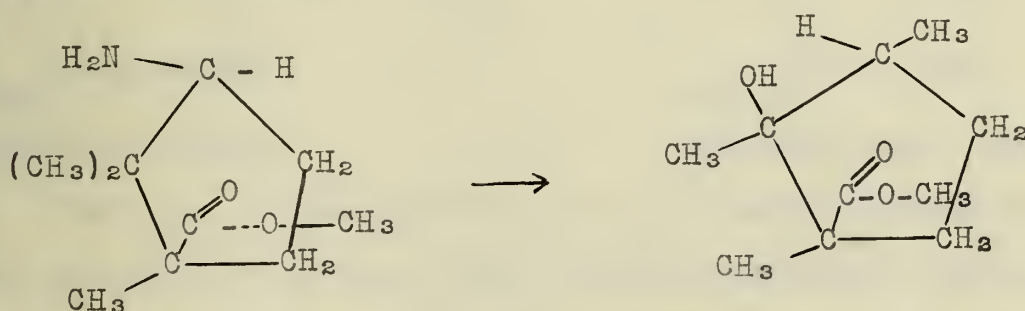
In the nitrite decomposition of an aliphatic amine the alcohol produced often has the hydroxyl group on a carbon atom different from the one to which the amino group was originally linked. Henry<sup>1</sup> has found the following results and concludes this change takes place to a greater extent as the number of methyl groups on the carbon is greater.

1. C. Rend. 145 899, 1247, (1907)





It thus appears that the hydroxyl tends to shift to the carbon bearing the most methyl groups. This would indicate that the hydroxyl would go in large part to the carbon bearing the gem methyl but this could be accomplished only by the shifting of one of the methyl groups and a tertiary alcohol containing a 1,2,3 trimethyl grouping would result. Thus,



We have some evidence that such a compound is formed in this decomposition.

In the normal decomposition in which no intramolecular rearrangement has occurred trans-camphonolic acid (not yet prepared) should result, but so far we have no evidence of the formation of





such a compound. We also have some evidence that a compound containing a secondary hydroxyl on the other  $\beta$  carbon is formed.

A  $\gamma, \delta$  unsaturated acid would be normally expected in this decomposition, which acid should give camphoronic acid by oxidation but no camphoronic acid was obtained. If it is true that the hydroxyl and methyl groups exchange places it is reasonable to think that the double union would also appear here and that lauronolic acid would result. We have some evidence that this is the case.

It should be noticed at this point that when an unsaturated acid especially in this series, is placed under strain the double bond tends to move toward the carboxyl. A straight chain  <sup>$\beta, \gamma$</sup>  unsaturated acid by heating with dilute acids is changed to an  $\alpha, \beta$  unsaturated acid. In this series it has been definitely shown that a  $\gamma, \delta$  unsaturated acid by the same treatment rearranged into an  $\alpha, \beta$  unsaturated acid.

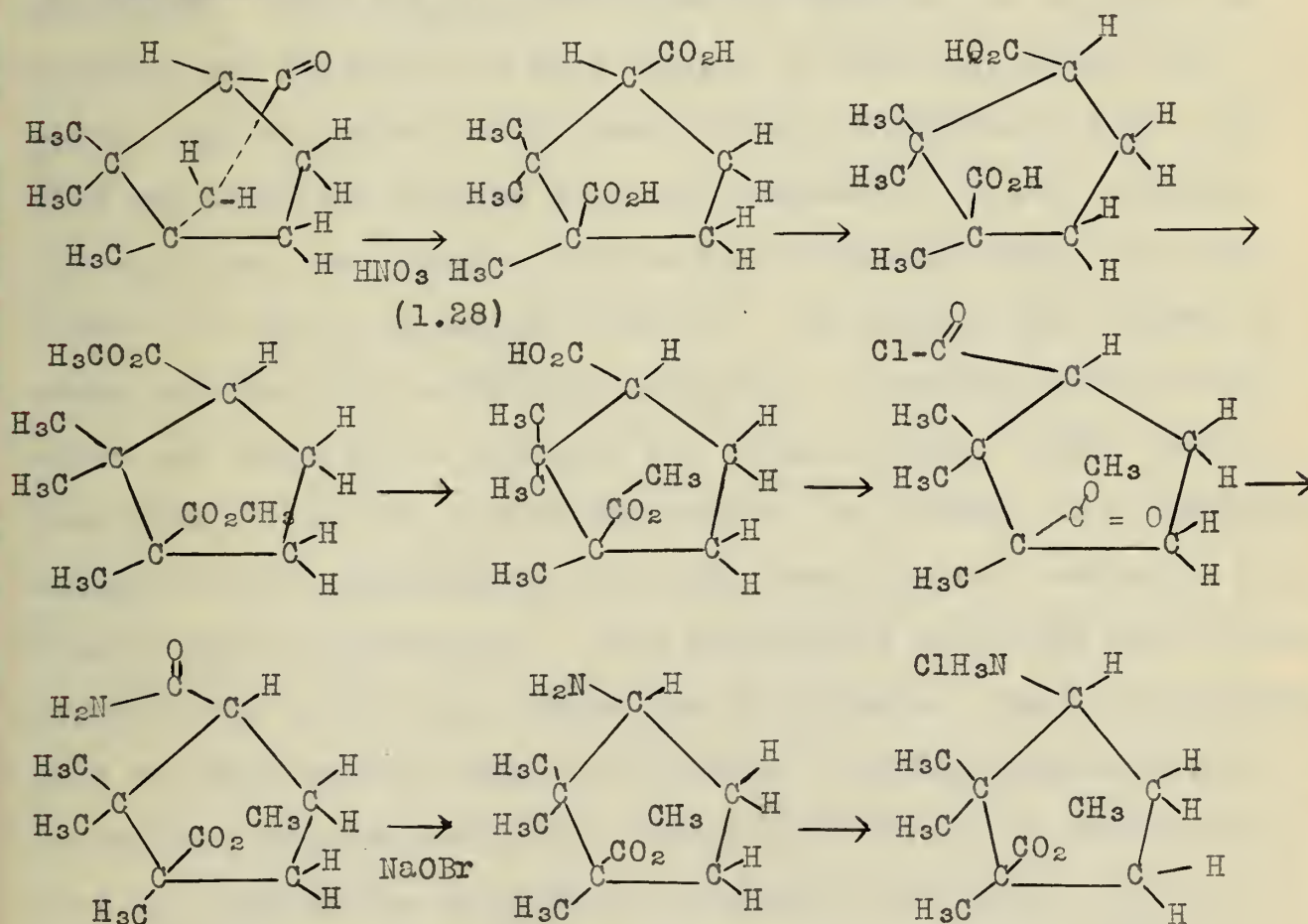


However, in the case of the  $\gamma, \delta$  unsaturated acid that would normally be obtained from isoaminocamphonanolic acid, a shift of the double union to the  $\beta, \gamma$  position would not be expected by analogy since this carboxyl is tertiary instead of secondary. The possibility then remains that the shift would be to the  $\beta, \gamma$  position which we have found to be the case.



The formation of hydrocarbons in the decomposition of the amino acids is difficult to explain. The loss of carbon dioxide by these unsaturated acids may be analagous to the ketonic decomposition of  $\beta$ -ketonic acids, in which the double union plays the role of the carbonyl. Also the loss of carbon dioxide in these reactions may be closely related to the loss of carbon dioxide by an ion of an organic acid, when it loses its negative charge.<sup>1</sup> One would not expect a hydrocarbon to be formed in the decomposition of the ester and this has been confirmed by experiment.

The method of Noyes and Littleton<sup>2</sup> was used in the preparation of the materials and is indicated as follows:



1. J. Am. Ch. Soc., 32, 1070

2. J. Am. Ch. Soc., 35, 77





### III EXPERIMENTAL.

#### Preparation of l-Isocamphoric Acid.

Eight sealed tubes each containing 50 grams d-camphoric acid, 25 cc. glacial acetic acid and 2 cc. hydrochloric acid (1.20) were heated in a bomb furnace at a temperature of  $175^{\circ}$  -  $185^{\circ}$  for ten hours. After cooling the tubes opened under pressure. The semi-crystalline contents were poured into a liter of cold water, the tubes being washed out with hot water. The material was stirred as often as needful to prevent solidification into unnecessarily large particles. After allowing to stand for one hour the crystalline material was filtered off with the aid of suction, washed with water, and then dried on the steam bath in a porcelain dish. To this was added the residue from the evaporation of the filtrate. The whole was then finely powdered and thoroughly mixed with one-fourth its weight of acetyl chloride. The mixture was allowed to stand one hour with occasional stirring. A quantity of water was added and the material filtered off using suction. After washing free from acetic and hydrochloric acids, the mixture of d-camphoric anhydride and l-isocamphoric acid was treated with a saturated solution of sodium bicarbonate. The d-camphoric anhydride was filtered off and used in the next charge for the furnace. The l-isocamphoric acid was precipitated from the solution of sodium l-isocamphorate by means of hydrochloric acid. After standing ten or fifteen minutes the crystalline material was filtered off, washed and then dried on the steam bath. It was dissolved in a small quantity of alcohol, filtering if necessary. The excess of alcohol was boiled out and four or five volumes of boiling water added with



vigorous stirring. As the alcohol evaporates spontaneously the acid separates in fine white crystals throughout the liquid. This is a good way to remove the last traces of d-camphoric acid as the solubility of this acid is 6.96 grams per 100 grams of water, while that of l-isocamphoric acid is only 0.337 grams. M.P. =  $171.5^{\circ}$ - $172.5^{\circ}$ .  $\alpha_D^{28} = -46.8^{\circ}$ . Noyes and Littleton found  $\alpha_D = -47.6^{\circ}$ . Noyes and Knight found  $\alpha_D = -47.1$ . Aschan found,  $\alpha_D = -47.1$ . The yield was one-third the weight of the camphoric acid used and a total of 3450 grams was prepared.

#### Preparation of $\alpha, \beta$ -Methyl l-Isocamphorate.

Noyes and Littleton obtained this ester by boiling a solution of 200 grams of l-isocamphoric acid, 800 cc. of methyl alcohol and 80 cc. of concentrated sulphuric acid under a reflux for forty-eight hours. It was found that by using the materials in this proportion the yield was inappreciable after five hours, but if twice the quantity of sulphuric acid were used the yield was increased to 60% of the theory. The temperature of the boiling mixture due to this modification increases from  $71^{\circ}$  to  $78^{\circ}$ . The methyl alcohol was distilled first at atmospheric and then under diminished pressure. The mixture of esters was precipitated by the addition of cold water. The water layer was separated and the oily layer was repeatedly shaken in a separatory funnel with a strong solution of sodium bicarbonate to remove the  $\alpha$ -methyl ester. The alkaline solution was repeatedly extracted with ether. The ether extract of the  $\alpha, \beta$ -methyl ester was dried with anhydrous sodium sulphate and the ether completely removed on the steam bath with the aid of a capillary under diminished pressure. The ester as obtained by







distillation under diminished pressure is a clear oily liquid.

B.P. =  $145^{\circ}$  (22mm.) :  $137^{\circ}$  -  $140^{\circ}$  (12 - 14 mm. ) :  $130^{\circ}$  -  $132^{\circ}$

(8 - 10 mm);  $144^{\circ}$  (19 mm.)  $141^{\circ}$  -  $142^{\circ}$  (16 mm.) The rotation was

$\alpha_D^{24.5^{\circ}} = -65.5^{\circ}$ . For a solution in absolute alcohol containing .107 gm/cc the rotation was  $\alpha_D^{22^{\circ}} = -66.5$ . Noyes and Knight found

B.P. =  $146^{\circ}$  (27 mm.)  $\alpha_D = -65.2^{\circ}$ . Some representative experiments are given in the appended tabel:

| Exp. | : 1-Isocam-<br>phoric<br>Acid | : Acid<br>Ester | :<br>:  | :<br>: | :<br>:  | : Yield of<br>Acid<br>Ester. | : Yield of<br>Dimethyl<br>Ester. |
|------|-------------------------------|-----------------|---------|--------|---------|------------------------------|----------------------------------|
| 1    | : 300 gm.                     | :               | : 1200: | : 240  | : 6 hr: | : 160                        | :                                |
|      | :                             | :               | : cc.:  | : cc   | :       | :                            | :                                |
| 2    | : 243                         | : 80 gm:        | : 1300: | : 248  | : 12 ": | : 82                         | :                                |
|      | :                             | :               | : :     | :      | :       | :                            | :                                |
| 3    | : 58                          | : 242 "         | : 1200: | : 240  | : 14 ": | : 80                         | : 900 gms.                       |
|      | :                             | :               | : :     | :      | :       | :                            | :                                |
| 4.   | : 225                         | : 80 "          | : 1220: | : 244  | : 16 ": | : 70                         | :                                |
|      | :                             | :               | : :     | :      | :       | :                            | :                                |
| 5.   | : 71                          | : 70 "          | : 560:  | : 112  | : 14 ": | : 43                         | :                                |

#### $\alpha$ -Methyl 1-Isocamphorate.

The  $\alpha$  - methyl ester was precipitated from the above bicarbonate solution with hydrochloric acid and recrystallized from petroleum ether in which it is difficultly soluble. It melted at  $88^{\circ}$  -  $89^{\circ}$ . Noyes and Knight found, M.P. =  $88^{\circ}$ .  $\alpha_D = -57.9^{\circ}$

#### Preparation of $\beta$ -Methyl 1-Isocamphorate.

To 100 grams of  $\alpha$ ,  $\beta$ -methyl 1-isocamphorate was added 100 cc. methyl alcohol and 110 cc. sodium hydroxide, (3cc. = 1 gm) (4% excess of one molecule) The mixture was heated on the steam bath under a reflux for 40 minutes. The methyl alcohol was distilled first at



atmospheric and then under diminished pressure. The residue was immediately dissolved in water, and the alkaline solution was repeatedly extracted with ether to remove the neutral ester. The  $\beta$ -methyl ester was precipitated with hydrochloric acid and extracted with ether. After the removal of the ether it remained as a very viscous liquid, which changed to a translucent solid having the appearance of glue when surrounded by ice water, but it did not crystalize. No attempt was made to distil it under diminished pressure, the probability being that it would undergo decomposition and rearrangement. The yield was 90% - 95% of the theory.

#### Preparation of $\beta$ -Methyl $\alpha$ -1-Isocamphoramidate.

The viscous  $\beta$ -methyl ester was warmed gently on the steam bath and then quickly dissolved in a small quantity of ligroin. This solution containing 165 grams of the ester was slowly added from a separatory funnel to a flask fitted with a reflux condenser, and containing 165 grams of phosphorus pentachloride covered with 300 cc. of petroleum ether (B.P. =  $25^{\circ}$  -  $40^{\circ}$ ). The contents of the flask were protected by means of calcium chloride. When the phosphorus chloride had disappeared the solution was diluted with 300 cc. of petroleum ether. This solution was added from a separatory funnel slowly with vigorous stirring to 750 cc. of ammonium hydroxide (0.90) which was kept at a temperature of  $-10^{\circ}$  by a freezing mixture of hydrochloric acid, ice and water. It is important that the temperature be kept low and that the ligroin solution be dilute, otherwise the yield is very poor. Most of the amide precipitated out in this process and was filtered off. After sucking dry on a plate, it is dissolved in the smallest possible quantity of warm alcohol in which





it is very soluble. After filtering four or five volumes of cold water were slowly added with stirring. In this manner 100 grams of a white crystalline product was obtained, which melted at  $127^{\circ}$  -  $128^{\circ}$  (cor.). The specific rotation was  $\alpha_D = -55.4^{\circ}$ . Noyes and Littleton found,  $\alpha_D = -54.1$ . M.P. =  $126 - 127$ . It is difficultly soluble in ether. By concentrating the alcoholic liquors the yield was increased to 133 gms. or 80% of the theory.

The ammoniacal liquors were evaporated on the steam bath until ammonium salts began to crystallize, the solution was acidified and the heavy oil extracted with ether. Upon treatment with sodium hydroxide a white crystalline substance (6 grams) separated, which was identified as the amide by its melting point. Upon acidification of the alkaline filtrate white crystals separated which were insoluble in ether. They were filtered off and washed first with water and then with ether. The melting point was indefinite at about  $215^{\circ}$ . The ether soluble material which was obtained as a very viscous liquid probably consisted mainly of the original acid ester.

#### Preparation of Methyl Isoaminocamphonanate.

To 10 grams of  $\beta$ -methyl  $\alpha$ -camphoramidate was added a solution (1.25 mol.) of sodium hypobromite freshly prepared by aspirating the vapor of 10 grams of bromine thru 100 cc. of a 10% solution of sodium hydroxide which was surrounded by ice water. Noyes and Littleton heated the mixture for fifty minutes, but this was found to be unnecessary, and undesirable since the saponification of the ester may become appreciable due to such long continued heating. The contents of the flask should be heated very slowly for the first



two or three minutes, frequently giving the flask a gentle rotatory notion. If the operation is carried out properly a clear yellow solution will result. On further heating the solution became turbid, the orange color instantaneously disappeared, and an almost colorless oil separated at the surface. The entire time necessary for the completion of the reaction was about five minutes. The contents of the reaction flask were cooled immediately, the alkaline solution extracted three times with small quantities of ether, and the ether extract shaken repeatedly with a dilute (1 : 1) solution of hydrochloric acid. Any unchanged amide remained in the ether layer, and was used again. The amine ester was precipitated from the acid solution by the addition of a slight excess of sodium hydroxide solution. The alkaline solution was extracted repeatedly with ether and after drying with anhydrous sodium sulphate the ether was removed and the amine ester distilled under diminished pressure. The portion boiling at  $135^{\circ} - 138^{\circ}$  (20 -22mm.) was obtained as a clear mobile oil which had a fishy odor. The specific rotation was  $\alpha_D^{26} = -49^{\circ}$ . For a solution in absolute alcohol containing .105 gm/cc,  $\alpha_D^{25} = -41.2^{\circ}$ .  $d^{25/4} = 1.0161$ . The high boiling residue which partly crystallized in the bulb has not yet been investigated. It is probably a condensation product formed at the temperature of the distillation. The ester which was used in determining the physical constants was obtained from the hydrochloride which had been recrystallized a second time from ether, and which had not been distilled.

#### Preparation of the Hydrochloride of Methyl Isoamino-camphonanate.

Dry gaseous hydrogen chloride was conducted to the surface of







an ethereal solution of the amine ester, which had not been distilled. The hydrochloride crystallized in long white needles, which melted at  $179^{\circ} - 180^{\circ}$  (cor.)  $\alpha_D = -42.2^{\circ}$ . Noyes and Littleton found for the monohydrate, M.P. =  $177^{\circ}$   $\alpha_D = -42.03^{\circ}$ . The yield was 70% of the theory calculated on the basis of the amide, in the later experiments, although at first poor results were obtained and much material was wasted in carrying out the hypobromite reaction.

#### Decomposition of Methyl Isoaminocamphonanate.

Twenty-five grams of the above hydrochloride were dissolved in 100 cc. of water. To this was added a solution of 8.4 grams (1.1mol) sodium nitrite in 25 cc. of water. A drop, or more if necessary, of hydrochloric acid was added to start the reaction, the reaction mixture, <sup>being</sup> kept very near room temperature by placing the flask in a dish of water. The reaction was usually complete in twenty-four hours. The oily product was extracted from the acid solution with ether and the ether extract was shaken with 10% sodium carbonate solution to remove the ether acid. The esters were then subjected to fractional distillation under diminished pressure, using a distilling bulb especially designed for the purpose. (Fig. I)

It has been found necessary, in order to obtain materials in sufficient quantity for study, to repeat several times the work thus far described. In Table II is to be found the results of the various decompositions. In Table III the per-centages are based upon the total weight of the products. Table IV shows the progress of the fractional distillation of the esters from the sixth decomposition. The fractionation was carried still further than is shown in the table but the figures presented show the efficiency of the method









of separation. The fractions were weighed to the nearest gram.

It has been uniformly noticed that water is always formed in distilling the fractions which boil at 100 - 120°. This must be due to the formation of unsaturated compounds from the hydroxy compounds by the loss of water.

Table II.

| No. | Wt. of Hydro-chloride | $C_8H_{13}CO_2CH_3$                              | Ether Acid | Campho-nolic Ester | Other esters of hydroxy acids | Total Wt of Product |
|-----|-----------------------|--|------------|--------------------|-------------------------------|---------------------|
| 1   | 40.5 gm               | (Attempted distillation at atmospheric pressure) |            |                    |                               | 21.5 gm             |
| 2   | 44.6 "                |  |            |                    |                               | 29.                 |
| 3   | (110 gm)              |  |            |                    |                               | 64.7 "              |
| 4   | 82 "                  | 22 gm  | 9.6 gm     | 12 gm              | 8 gm                          | 42 "                |
| 5   | 225 "                 | 59 "   | 18.4 "     | 38 "               | 28 "                          | 144 "               |
| 6   | 345 "                 | 85 "   | 28 "       | 59 "               | 44 "                          | 216 "               |

Table III.

| No | Ether Acid | Campho-nolic Ester | Esters of other hydroxy acids | $C_8H_{13}CO_2CH_3$ |
|----|------------|--------------------|-------------------------------|---------------------|
| 5  | 13%        | 26%                | 20%                           | 41%                 |
| 6  | 13%        | 27%                | 20%                           | 40%                 |



Table IV.

| No  | B. P.                            | Bath                               | Pressure | Weight    |
|-----|----------------------------------|------------------------------------|----------|-----------|
| A*  |                                  |                                    |          |           |
| 1   | 90 <sup>0</sup> -95 <sup>0</sup> | 110 <sup>0</sup> -120 <sup>0</sup> | 20 mm.   | 50 gms.   |
| 2   | 95 -100                          |                                    | 20 mm.   | 29 gms    |
| 3   | 100 -108                         | 130                                | 20 mm.   | 18 gms    |
| 4   | 108 -120                         |                                    | 20       | 16        |
| 5   | 120 -130                         | 140 -145                           | 20       | 22        |
| 6   | 130 -142                         | 160 -                              | 20-21    | 53/188gms |
| B** |                                  |                                    |          |           |
| 1   | 83 -88                           | 120 -130                           | 20       | 35        |
| 2   | 85 -92                           | 120 -130                           | 20       | 31        |
| 3   | 86 -95                           | 120 -135                           | 20       | 21        |
| 4   | 90 -105                          | 135 -                              | 20       | 12        |
| 5   | 105 -120                         | 145 -160                           | 21       | 22        |
| 6   | 120 127                          | 150 -165                           | 21       | 33        |
| 7   | 127 -135                         | 180 -190                           | 21       | 29        |
| 8   | 135 -142                         | 180 -220                           | 21       | 39/221    |
| C   |                                  |                                    |          |           |
| 1   | -86                              | 120                                | 21       | 35        |
| 2   | 86 -90                           | 120 -130                           | 21       | 34        |
| 3   | 88 -93                           | 115 -145                           | 21       | 22        |
| 4   | 93 -110                          | 140 -150                           | 22       | 9         |
| 5   | 110 -120                         | 140 -150                           | 22       | 23        |
| 6   | 120 -125                         | 140 -150                           | 21       | 32        |
| 7   | 125 -135                         | 160 -                              | 21       | 22        |
| 8   | 133 -137                         | 160                                | 20       | 19        |
| 9   | 137 -139                         | 165 -170                           | 20       | 22/218    |
| D   |                                  |                                    |          |           |
| 1   | 79 -83                           | 115                                | 15       | 37        |
| 2   | 79 -83                           | 105                                | 15       | 34        |
| 3   | 80 -86                           | 110 -115                           | 15       | 17        |
| 4   | 86 -105                          | 120 -140                           | 15       | 8         |
| 5   | 105 -112                         | 140 -145                           | 15       | 32        |
| 6   | 112 -120                         | 140 -150                           | 15       | 25        |
| 7   | 120 -126                         | 150                                | 15       | 4         |
| 8   | 126 -134                         | 165 -175                           | 15       | 13        |
| 9   | 134 -136                         | 165 -175                           | 15       | 44/214    |
| E   |                                  |                                    |          |           |
| 1.  | 81 -81.5                         | 105 -110                           | 16       | 39        |
| 2   | 81.5-84                          | 105 -110                           | 16       | 38        |
| 3   | 84 -105                          | 125 -135                           | 16       | 11        |
| 4   | 105 -112                         | 160                                | 16       | 20        |
| 5   | 112 -115                         | 145 -150                           | 16       | 32        |
| 6   | 115 -122                         | 160                                | 16       | 21        |
| 7   | 122 -135                         | 160                                | 16       | 16        |
| 8+  | 134 -135                         | 160 -170                           | 16       | 46/224    |
| -9  |                                  |                                    |          |           |
| F   |                                  |                                    |          |           |





Table IV. (Continued)

| F |  |          |    |    |
|---|--|----------|----|----|
| 1 | 78.5 -79                               | 100 -105 | 15 | 50 |
| 2 | 79 -85                                 | 105 -110 | 15 | 28 |
| 3 | 85 -108                                | 125 -145 | 15 | 8  |
| 4 | 108 -112                               | 140      | 15 | 5  |
| 5 | 110 -114                               | 140 -145 | 15 | 38 |
| 6 | 112 -120                               | 145 -150 | 15 | 8  |
| 7 | 120 -135                               | 160      | 15 | 7  |
| 8 | 135                                    |          |    | 6  |
| 9 | (E - 8) + (D - 9) were not redistilled |          |    |    |

\* Without fractionating column. Distilled into about 30 gms of intermediate fractions from previous decomposition at the proper times.

\*\*With fractionating column. The non-agreement between the subsequent weight totals is due to the inaccuracy of weighing and to the fact that the residues were not uniformly taken into account.

#### The Methyl Esters of the Unsaturated Acids.

The fraction boiling at 86°-88° (21 mm.) from decomposition No. I was analyzed with the following results:

|                     | Carbon | Hydrogen |
|---------------------|--------|----------|
| 1. Found            | 70.78% | 9.47%    |
| 2. Found            | 71.35  | 9.32     |
| Calculated for      |        |          |
| $C_8H_{13}CO_2CH_3$ | 71.37  | 9.59     |

In Table V are given the physical constants which have been determined on the lowest boiling fraction from the various decompositions.

The purest sample of the ester is evidently that obtained in the sixth experiment. Here a product weighing fifty grams and boiling constantly was obtained with the special fractionating apparatus. Our results show that all unsaturated compounds are to be found in this fraction. The ester was obtained as a light colorless oil having a somewhat pungent odor. The boiling point changes very rapidly



with the pressure at the pressures used. It boils at 75° under 9mm.

Table V.

| No. | B.P.    | (mm)<br>Pres-<br>sure | Rotation in<br>absolute<br>alcohol | Concen-<br>tration<br>gm/cc. | Temp | Rotation of<br>liquid<br>ester | Temp. | d 20/4 |
|-----|---------|-----------------------|------------------------------------|------------------------------|------|--------------------------------|-------|--------|
| 1   | 86-88   | 21                    | 84.9°                              | .08700                       | 29°  | 89.6°                          | 29°   | .9655  |
| 2   | 79-84   | 16                    | 84.7                               | .08228                       | 28°  | 87.6°                          | 27°   | .9660  |
| 3   | 81-84   | 18                    | 76.5                               | .1182                        | 29°  |                                |       |        |
| 4   | 80-90   | 15                    |                                    |                              |      |                                |       |        |
| 5   | 80-85   | 18                    |                                    |                              |      |                                |       |        |
| 6   | 78.5-79 | 15                    | 74.4                               | .1043                        | 24°  | 76.6                           | 26.5° | .9637  |

| No. | d25/4 | N <sub>c</sub> <sup>25°</sup> | N <sub>d</sub> <sup>25°</sup> | N <sub>f</sub> <sup>25°</sup> | N <sub>G</sub> <sup>25°</sup> | Dispersion<br>G - C | F - C  | D - C  |
|-----|-------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|---------------------|--------|--------|
| 6   | .9594 | 1.45454                       | 1.45755                       | 1.46423                       | 1.4697                        | .0152               | .00969 | .00301 |

### The Methyl Esters of the Intermediate Hydroxy Acids.

Seventeen hundred grams of 1-Isocamphoric acid yielded forty grams of a product boiling at 112°-114° (18 mm.) Analysis gave the following results:

| Found.   | C.     | H.    |
|--|--------|-------|
| I  | 64.51% | 9.44% |
| II   | 64.27  | 8.96  |
| III  | 64.55  | 9.33  |
| Calculated for C <sub>8</sub> H <sub>14</sub> <sup>OH</sup> -CO <sub>2</sub> CH <sub>3</sub> | 64.46  | 9.74  |
| Calculated for C <sub>8</sub> H <sub>13</sub> CO <sub>2</sub> CH <sub>3</sub>                | 71.37  | 9.59  |
| Calculated for C <sub>8</sub> H <sub>14</sub> <sup>O</sup> = 0                               | 70.07  | 9.15  |

The substance gave the following constants:

$$\alpha_{D^{27.50}} d_{20/4} = 1.040; d_{25/4} = 1.035$$

$$D_{27.50} = 20.3$$

For a solution in absolute alcohol containing .1105 gm/cc,

$$\alpha_{D^{29.5}} = 18.6$$





It has since been shown that the substance, although carefully fractionated with the fractionating apparatus, is a mixture of the methyl esters of perhaps three hydroxy acids.

#### Hydrocarbons.

After distilling off the ether from the ethereal solution of the esters the ether was distilled from a Ladenburg distilling bulb. The small amount of residue was distilled at atmospheric pressure in a small bulb. The temperature rose almost immediately to about  $200^{\circ}$ . As the last traces of ether had been removed from the ester on the steam bath at a pressure of 30 -40 mm., it is at once evident that no hydrocarbon was formed in the decomposition

#### Methyl Ester of Cis-Camphonolic Acid.

The fraction from the second decomposition boiling at  $125^{\circ}$ - $135^{\circ}$  (17 mm.), which was obtained as a heavy colorless oil was analyzed.

|   | <u>Carbon</u> | <u>Hydrogen</u> |
|---|---------------|-----------------|
| Calculated for $C_8H_{14}\overset{OH}{\diagup}CO_2CH_3$ | 65.08%        | 9.70%           |
|   | 64.46         | 9.80            |

The rotation for the liquid ester was  $\alpha_D^{26^{\circ}} = 10.35$  and for a solution in absolute alcohol containing .0828 gms/cc  $\alpha_D^{26^{\circ}} = 10.26$ . It was of course impure; however the pure ester has been prepared from the silver salt of cis-camphonolic acid and will be discussed later.

#### The Methyl Ether of Cis Camphonolic Acid.

The free acid from the higher boiling fractions, which crystallized in the receiver, was extracted with 10% sodium carbonate solution. By slow crystallization from a mixture of ether and low boiling ligroin, large monoclinic prisms were obtained, the largest being



two centimeters in length. The specific rotation of a solution in absolute alcohol containing .0455 gms/cc was  $\alpha_D^{28} = 72.1^\circ$  M.P.=87° (cor.). A portion dissolved in alcohol and partially precipitated by the careful addition of water gave the same melting point (87 - 87.5) The substance was analyzed for carbon and hydrogen with the following results:

|  | <u>Carbon</u> | <u>Hydrogen</u> |
|--|---------------|-----------------|
| Found  |               |                 |
| Calculated for $C_8H_{14}\begin{smallmatrix} OCH_3 \\ CO_2H \end{smallmatrix}$ | 63.82         | 9.84            |
|  | 64.46         | 9.74            |
| Calculated for $C_8H_{14}\begin{smallmatrix} CO_2H \\ OH \end{smallmatrix}$    | 62.74         | 9.37            |

A rough Zeisel determination gave 15.5%  $-OCH_3$  while theory requires 16.6%. These analyses were not repeated for want of time.

The acid is volatile with steam and this volatility is increased by distilling from a saturated salt solution. The melting point of the acid obtained in this way was 87 - 88°

The melting point of a mixture of this acid and the ether acid (M.P. = 84°) obtained from isocampholactone was 45-50. The mixture first became pasty and then melted gradually to a clear liquid. The two acids are therefore different.

The acid is not converted to the lactone by heating at 255° for fifteen minutes.

No camphononic acid was obtained by treatment with Beckmann's chromic acid mixture under the conditions used for cis-camphonolic acid.

An attempt was made to prepare the hydriodide with a view to obtaining an unsaturated acid which might give some indication of its structure. Five-tenths of a gram of the acid was dissolved in carbon disulphide in which it is easily soluble. Gaseous hydrogen iodide





was passed into the solution until the dark brown precipitate, which formed at first, no longer increased in amount. The product was extremely unstable and the melting point was indefinite at 60°- 65°. It slowly decomposed on standing. After remaining in a desiccator over night it was warmed on the steam bath with 5% sodium carbonate solution until a white crystalline substance remained, which was then extracted with ether. A few selected crystals melted at 160 - 161°. This was shown to be identical with cis-camphonololactone by the mixed melting point.

The silver salt was prepared by dissolving 11.2979 grams of the acid (.06075 mols) in 20.4 cc. (.06075 mols) of 2.98 N carbonate free sodium hydroxide diluted with 25 cc. of water and precipitating with a strong solution of silver nitrate containing 11.5 gm AgNO<sub>3</sub>. The silver nitrate was filtered with suction on a Hirsch funnel and washed with cold water, alcohol, and finally with ether. The yield of the salt dried in vacuo over sulfuric acid was 17 grams. The salt dried at 100° for a half hour gave the following analysis:

| I  |               | II       |  |
|--|---------------|----------|--|
| .1119 gm   | Wt. of Salt   | .1183 gm |  |
| .0412  | " " Ag        | .0436    |  |
| 36.81  | Percent of Ag | 36.85    |  |
| Calculated for $C_8H_{14}-\overset{OCH_3}{\overline{CO_2H}} = 36.82$ |               |          |  |

Ten grams of the above silver salt was covered with anhydrous ether in a flask sealed to an inner tube of a water condenser. To this was carefully added eight grams of methyl iodide dissolved in anhydrous ether. The contents of the flask were protected from the light and allowed to reflux gently on the steam bath for about six hours. The silver iodide and any unchanged silver salt was filtered off, the acid substances were removed by shaking with sodium carbonate



solution, and the ether and excess methyl iodide were distilled from the residual ester on the steam bath. The ester has a very pleasant odor and distilled at 116°-118° (29-28 mm) The temperature of the Wood's metal bath was 135°-140°. For a solution in absolute alcohol containing .0903 gm/cc.  $\alpha_D^{20} = 64.7^\circ$   $d_{20/4}^{25} = 1.0041$   $d_{20/4} = 1.0082$  The yield was three grams. The sodium carbonate extract from above upon acidification gave one gram of a crystalline product melting at 80°-85°, evidently the impure ether acid.

#### The Unsaturated Acid.

The methyl ester of the unsaturated acid was dissolved in alcohol and saponified by refluxing 48 hours with 1.5 mols. sodium hydroxide, using a solution of which three cc. were equivalent to one gram NaOH. The alcohol was distilled under diminished pressure in a comparatively large Claissen bulb. The residue was dissolved in water and, after filtering, the acid was taken up in ether from the acidified solution. The ester from the various nitrite decompositions gave an acid having the following physical constants.

In the earlier experiments an attempt was made to establish its structure by oxidation with nitric acid. Five-tenths of a gram of the acid, 2 cc. of water, and 3 cc. of nitric acid (1.40) were placed in a long narrow test tube and the mixture was heated on the steam bath for a half hour. The reaction was vigorous at first and solution resulted in a few minutes. The contents of the tube were poured into a porcelain dish and evaporated to dryness. A light yellow crystalline residue remained which dissolved to a dark orange colored solution with 10% sodium hydroxide, indicating the presence of nitro compounds. After filtering a dilute solution of barium





chloride was added and any precipitate was filtered off in the cold. The filtrate was heated to boiling and the slight amount of precipitate was filtered. A few drops of hydrochloric acid were added and then allowed to evaporate on a watch glass. The residue was extracted with a little absolute alcohol which was allowed to evaporate on a watch glass. The residue was dissolved in a few drops of water and allowed to crystallize. The crystals melted indefinitely at about  $150^{\circ}$ . Some l-camphoronic acid melted indefinitely at about the same temperature; as the yield was so very small this method of procedure was discontinued.

Table VI.

| No: | B . P.  | : Pres-<br>: sure<br>: (mm) | : Rotation<br>: in<br>: absolute<br>: alcohol | : Conc.<br>: gm/cc. | : Temp:      | : Rotation:<br>: of<br>: liquid<br>: acid | : Temp       | : d $20^{\circ}/4$ |
|-----|---------|-----------------------------|---|---------------------|--------------|---|--------------|--------------------|
| 1   | 142?    | 21                          | 84.5  | .08874              | $28^{\circ}$ |   |              | 1.017              |
| 2   | 145-147 | 25                          | 88.4  | .08352              | 30           | 113.2                                     | $31^{\circ}$ | 1.0128             |
| 3   | 135-138 | 18                          | 81.2  | .0941               | 29           |   |              |                    |
| 4   | 132-135 | 10                          |   |                     |              |   |              |                    |
| 5   | 139     | 19                          |   |                     |              |   |              |                    |
| 6   | 135     | 14                          | 83.4  | .1014               | 25           | 105.2                                     | 25           | 1.0132             |

| Dispersion |                  |                               |                               |                               |                                |          |                   |
|------------|------------------|-------------------------------|-------------------------------|-------------------------------|--------------------------------|----------|-------------------|
| No:        | d $25^{\circ}/4$ | : N <sub>c</sub> $25^{\circ}$ | : N <sub>D</sub> $25^{\circ}$ | : N <sub>F</sub> $25^{\circ}$ | : N <sub>G'</sub> $25^{\circ}$ | : G' - C | : F - C : D - C   |
| 1          | 1.013            | :                             | :                             | :                             | :                              | :        | :                 |
| 2          | :                | :                             | :                             | :                             | :                              | :        | :                 |
| 3          | :                | :                             | :                             | :                             | :                              | :        | :                 |
| 4          | :                | :                             | :                             | :                             | :                              | :        | :                 |
| 5          | :                | :                             | :                             | :                             | :                              | :        | :                 |
| 6          | 1.0088           | :1.47256                      | :1.47560                      | :1.48279                      | :1.48887                       | : .01631 | : .01023 : .00304 |



In the later oxidation experiments potassium permanganate in alkaline solution was used. By this method better results were obtained by using a very large excess of permanganate. When slightly more than the theoretical amount was used the oxidation product remained as a viscous liquid. Many experiments were made under different conditions but those which gave the best results are here described. In one case oxalic acid was isolated and identified by its melting point, titration, and analysis of calcium salt for calcium.

Five grams of the acid was dissolved in 11.6 cc of 2.98 N sodium hydroxide (10% excess) with the addition of 50 cc. of water. To this solution cooled in ice was added dropwise with constant shaking a solution of 18 grams of  $\text{KMnO}_4$  (Theory = 13.4 gm) in 300 cc. of water. The mixture was allowed to stand five hours at room temperature and then heated to the temperature of the steam bath with constant shaking. The  $\text{KMnO}_4$  was decolorized. The manganese oxides were filtered hot using suction. The filtrate was almost neutralized with HCl and the oxidation product was precipitated from the faintly alkaline solution by addition of  $\text{BaCl}_2$  solution in the cold. The gelatinous precipitate was allowed to settle and filtered with suction. An excess of HCl was added and the water was evaporated in a vacuum desiccator over soda-lime and calcium chloride. The pulverized material was extracted repeatedly with ether. The ether residue was dissolved in water and the aqueous solution was concentrated in a vacuum desiccator. The crystals melted with a decomposition at about  $160^\circ$  and the weight was .25 grams.

.0582 grams                      17.9 cc    .05048 N KOH

Calculated for  $\text{C}_9\text{H}_{14}\text{O}_6$ , 17.8 cc.



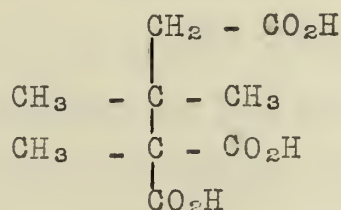
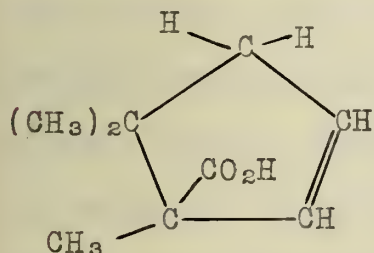


Two and five-tenths grams of the acid was dissolved in 5.5 cc of 2.98 N NaOH. To this solution was added a solution of 10.5 grams  $\text{KMnO}_4$  in 200 cc. of water in the manner indicated above. The permanganate color disappeared on standing and 20 hours later a solution of 5.2 gm.  $\text{KMnO}_4$  in 100 cc. of water was added. The mixture was allowed to stand about five hours longer. The excess permanganate was destroyed by adding a little methyl alcohol. The barium salt of the acid was treated as above and the free acid was extracted with absolute alcohol. It was crystallized again from water, separating in large transparent crystals. They melted at  $145^\circ$ - $150^\circ$  with decomposition to a clear liquid which did not crystallize again on cooling. When heated rapidly the melting point was  $155^\circ$ - $158^\circ$  (cor.) The yield was approximately .2 grams. A solution in absolute alcohol containing .0371 gm/cc showed no optical rotation.

.1251 gm neutralized 23.1 cc .0837 N KOH

Calculated for  $\text{C}_9\text{H}_{14}\text{O}_6$  23.1 cc

The only acid that could be obtained in this decomposition which would give an optically inactive tribasic acid of the above molecular weight is the following:



The filtrate from the barium salt gave no precipitate of barium 1-camphoronate when heated to boiling.

The amide prepared in the manner used for lauronic acid did not crystallize.



Hoping to obtain a crystalline derivative Mulliken's method of preparing toluides<sup>1</sup> was tried, but no toluides was obtained by this method. The toluides obtained by treating the acid chloride with p-toluidine was a viscous liquid which did not crystallize.

The preparation of the p-nitro benzyl ester was next tried. Seventy-one hundredths of a gram of the acid was dissolved in 1.56 cc 2.98 N sodium hydroxide with the addition of 3.44 cc of water. To this was added 1.0 gram of p-nitro benzyl bromide dissolved in 10 cc of 95% alcohol. The mixture was heated on the steam bath under a reflux for forty minutes. Turbidity appeared after about five minutes heating. To keep the ester in solution about 5 cc of a 1:2 solution of water in alcohol was added during the first 15 or 20 minutes. The reaction mixture was cooled quickly by shaking the flask under cold running water. A mobile yellow oil precipitated.

One and five-tenths grams of the acid was dissolved in 10 cc concentrated  $H_2SO_4$  cooled with a freezing mixture of  $HCl$  and ice. Fifteen cc cold  $HNO_3$  (1.42) was added one-half cc at a time. After each addition the contents of the long tube were shaken without removing from the freezing mixture. The reaction was vigorous at first but no brown fumes to speak of were evolved after the first addition. Nothing precipitated when a small portion was poured on finely crushed ice. When a small portion was warmed on the steam bath a vigorous oxidation resulted. The whole was therefore poured into ice water and extracted with ether. The ether extract was washed twice with water to remove the nitric acid. A viscous oil was obtained which would not crystallize.





A drop of the acid was placed on each of 48 small watch glasses in a vacuum desiccator, Evacuated to 20 mm. and then passed in  $\text{NO}_2$ , obtained by heating lead nitrate, until atmospheric pressure was almost restored. The acid turned green but no crystalline material separated then or after standing out of doors all night. The watch glasses were accordingly placed in a beaker and washed with ether. The extract was shaken with 10% sodium carbonate solution to remove the unchanged acid. The residue from the evaporation of the ether partly crystallized and after pressing out on porous porcelain the melting point was  $144-150^\circ$ . Recrystallization from a mixture of ether and petroleum ether gave transparent needles melting at  $171^\circ-173^\circ$ . The rotation for a solution in absolute alcohol containing .0088 gm/cc was  $\alpha_D^{25} = -8^\circ$  Schryver<sup>1</sup> gives M.P. =  $170^\circ$ . Noyes and Tippet<sup>2</sup> give M.P. =  $171^\circ$

This unsaturated acid should give a dihydro acid which is different from dihydrolauronolic acid. About thirty grams of the unsaturated acid was wasted in efforts to obtain such a dihydro acid, in which reduction experiments were carried out with zinc dust and absolute alcohol in the manner by which dihydrolauronolic acid was obtained and also with colloidal palladium. Two representative experiments for the reduction with zinc dust are here given.

Six grams of the unsaturated acid was dissolved in carbon disulphide in a U-tube surrounded by a freezing mixture of hydrochloric acid and ice. Gaseous hydrogen iodide was passed slowly through the solution for an afternoon. The hydriodide did not precipitate. The carbon disulphide was evaporated in a current of dry air and finally under diminished pressure keeping cold. The residue

1. J.Chem. Soc., 73, 550

2. Master's Thesis. Univ. of Ill.



was dissolved in absolute alcohol and an excess of Zn dust was added. The yellow color at once disappeared. About one cc. of fuming HI was added after a few minutes, and gaseous HI was passed into the solution. Finally some concentrated HCl was added. When all of the zinc had disappeared the mixture was diluted with water and extracted with ether. The ether extract was shaken with sodium carbonate solution to separate the lactone. The ether residue was an oil which did not crystallize on standing at room temperature. The sodium carbonate solution reduced instantly a strong permanganate solution which was added until the pink color remained. The manganese oxides were reduced by passing in sulfur dioxide keeping cold. Some sulfuric acid was added and the product was distilled with steam. The quantity of oil separating in the receiver was very small.

The experiment was carried out in another way by passing in the HI rapidly for a short time. The carbon disulphide residue was a viscous liquid. An emulsion of zinc dust in absolute alcohol was added at once with shaking. One or two cc. of fuming HI was added and then gradually with shaking and cooling a few cc of HCl. After about fifteen minutes the insoluble material was filtered off on a small Hirsch funnel, washing with a little petroleum ether. The filtrate was diluted with an equal volume of water and extracted with petroleum ether. In this way no bothersome precipitate of inorganic matter resulted when this solution was shaken with sodium carbonate solution to separate the acids from the lactone. Large transparent plates remained after evaporation of the petroleum ether. M.P. =  $45^{\circ}$ - $52^{\circ}$  The weight was .7 grams. The dihydro acid was separ-





ated from the unsaturated acid as before. The steam distillate was rather more turbid this time showing that better results had been obtained.

The supposed dihydro acid obtained from 24 grams of unsaturated acid weighed 2.4 grams and distilled at  $100^{\circ}$ - $130^{\circ}$  (15 mm) This product reduced permanganate instantly and consisted chiefly of the unsaturated acid. The portion which did not dissolve in sodium carbonate weighed one gram and distilled over a range of temperature at about  $90^{\circ}$  (15 mm)

When  $\text{SO}_2$  was passed in to decompose the oxides of manganese a small amount of a white crystalline substance always remained. This was filtered off and gave a melting point of  $85$ - $92^{\circ}$

When the above lactone was recrystallized from petroleum ether it melted sharply at  $49.5^{\circ}$  -  $50.5^{\circ}$  The rotation for a solution in absolute alcohol containing .05926 gm/cc was  $\alpha_D^{24} = -26.5^{\circ}$  Noyes<sup>1</sup> gives M.P. =  $48$  - $49$  for the lactone obtained from  $\gamma$ -lauronic acid. Noyes and Burke<sup>2</sup> give, M.P. =  $50^{\circ}$ ;  $\alpha_D^{22} = -21.7^{\circ}$  for the lactone obtained from lauronic acid. The writer has prepared the lactone from lauronic acid and found it to be identical with this lactone by determination of the mixed melting point.

Six-tenths of a gram of the lactone was dissolved in alcohol and refluxed on the steam bath for an afternoon with 1.5 cc. NaOH ( 3 cc. = 1 gm) The alcohol was distilled off completely, the residue was taken up in water and the solution filtered. The filtrate was cooled in a freezing mixture and the acid was

- 
1. J. Am. Chem 17, 434
  2. J. Am. Chem Soc., 34, 182



precipitated with the addition of ice cold hydrochloric acid. The white crystals melted at 143°-145° (uncor.) The rotation for a solution in absolute alcohol containing .0379 gm/cc was  $\alpha_D^{24.5} = 6^\circ$ <sup>1</sup>. Tiemann gives, M.P. = 145° Noyes and Burke give, M.P. = 143;  $\alpha_D^{27} = 16^\circ$ . The acid was titrated with the following results:

.1139 gm neutralized 13.16 cc .05048 N KOH

Calculated for  $C_8H_{14} \begin{array}{c} \text{OH} \\ \diagup \\ \text{CO}_2H \end{array}$  13.11 cc

An attempt was made to oxidize it to a ketonic acid but only the lactone and a very small amount of unchanged acid resulted.

Four-tenths of a gram of the acid was placed in a test-tube and to this was added 2 cc. of Beckmann's chromic acid mixture. After standing 22 hours it was diluted with 1.5 cc ( 1:1 H<sub>2</sub>SO<sub>4</sub>) and allowed to stand again for 50 hours. The green colored liquid was diluted with water and extracted with ether. The residue from the ether was dissolved in a few drops of benzene. Two or three volumes of petroleum ether was added. The crystals melted at 143 - 145. The solution was evaporated and white crystals were obtained which melted at 45°-48°

The same lactone was obtained from the unsaturated acid by heating with dilute acids. The following experiments are illustrative of the results obtained.

One gram of the unsaturated acid was placed in loosely stoppered test-tube with 10 cc ( 1:1) HCl and allowed to stand at approximately 50° for about 70 hours. The material which darkened considerably was subjected to steam distillation and the unchanged acid (.5 gm) was separated with sodium carbonate. The liquid lactone after standing out of doors at about the freezing temperature par-





tially crystallized and after pressing out on cold porous porcelain the crude lactone melted at  $45-48^{\circ}$ .

By shaking 1 gm. of the acid at the temperature of the steam bath with (1:2)  $\text{H}_2\text{SO}_4$  for 20 minutes, 0.2 gm. of the lactone and 0.7 gm. of unchanged acid were obtained. Slightly better results were obtained by the use (1:1)  $\text{H}_2\text{SO}_4$ , although there was more charring.

The colloidal palladium used in the reduction experiments was obtained by shaking a solution of gum arabic and palladous chloride in an atmosphere of hydrogen. Five grams<sup>1</sup> of the acid was dissolved in slight excess of sodium hydroxide and the solution was saturated with carbon dioxide. This was allowed to stand with colloidal palladium for two weeks in an atmosphere of hydrogen, which was under a pressure of about two feet of water. The mixture was shaken intermittently at a temperature of  $100^{\circ}$  by means of a mechanical shaking apparatus. No dihydro acid was obtained, although the palladium remained colloidal for the entire time.

The acid gives a Brom-lactone by the action of bromine. Two representative experiments are given below.

Two grams of the acid was dissolved in a few cc. of  $\text{CHCl}_3$  in a bulb. To this was added with shaking and cooling a solution of bromine in  $\text{CHCl}_3$  until the bromine color remained. Dense fumes of  $\text{HBr}$  were evolved. After evaporating the chloroform in a stream of dry air the semicrystalline residue was pressed out on porous porcelain to absorb any liquid material. The crystalline residue was then distilled with steam. It melted rather indefinitely at about  $183^{\circ}$ . The weight was 2 grams. By dissolving in methyl alcohol and

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1. Ber., 41, 2275 et al.; Ann., 388, 56

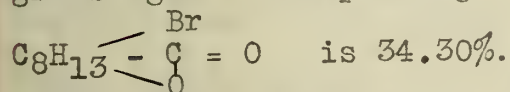


precipitating with an equal volume of water a product was obtained which melted at 191-192°. The weight was 1.4 grams.

In another experiment using the same amount of the unsaturated acid, the  $\text{CHCl}_3$  residue was dissolved in ether. The ether solution was shaken with sodium carbonate solution. The  $\text{Na}_2\text{CO}_3$  soluble material ( a very small amount) has not yet been investigated. The ether was evaporated from the ether layer and the residue (2gms) melted below 160° over a wide range. It was crystallized from petroleum ether in which it is not so soluble as it is in the other organic solvents. The melting point was then 186-187°. It was then crystallized repeatedly from hot ligroin (B.P.= 70) with the following results:

|     |                                |
|-----|--------------------------------|
| I   | M. P. = 187-188°*              |
| II  | M. P. = 190-191°               |
| III | M. P. = 191-192°               |
| IV  | M. P. = 192-193° (Wt. = .5 gm) |

.1395 grams of the substance by the Carius method gave .1132 grams  $\text{AgBr}$  corresponding to 34.53% Br. The bromine calculated for



The rotation of a sample of the lactone which had been distilled with steam but had not been recrystallized was for a solution in absolute alcohol containing .0937 gm/cc,  $\alpha_D^{24} = 48^\circ$ . This determination has not yet been repeated with the purest lactone obtained. The Br-lactone from lauronic acid has been prepared and the two are identical as shown by the mixed melting point.

The alcoholic solution of the brom-lactone from taking the rotation was saponified for 36 hours on the steam bath. The alcohol was boiled off, the residue was dissolved in water and the solution





was filtered. Some turbidity resulted upon acidification. The ether extract left a viscous residue. This was dissolved in 50% alcohol and the resulting solution was concentrated in vacuo over  $\text{CaCl}_2$ . Some oily drops separated at first but on complete evaporation a white crystalline residue remained, which melted at  $135-150^\circ$ . This was dissolved in ether containing a very little absolute alcohol. A white precipitate was obtained with petroleum ether which melted sharply at  $172-173^\circ$  (uncor.). The rotation for a solution in absolute alcohol containing .0077 gm/cc was  $\alpha_D^{25} = 6^\circ$ .

.0290 grams required 2.9 cc of .04979 N KOH for neutralization.

Calculated for  $\text{C}_8\text{H}_{13}(\text{OH})_2\text{CO}_2\text{H}$  ----- 3.0 cc  
 " "  $\text{C}_8\text{H}_{14}\text{---}\text{OH}\text{---}\text{CO}_2\text{H}$  ---- 3.4 cc.

Five-tenths of a gram of the unsaturated acid from one of the earlier preparations in which it was obtained in small quantity was distilled with powdered anhydrous zinc chloride. The distillate was distilled with steam to separate from the unchanged acid. The light oil was drawn off by means of a capillary in a narrow test tube. After drying with anhydrous sodium sulphate the boiling point as determined by the equilibrium method was  $120^\circ$ . Noyes and Burke obtained a boiling point of  $120^\circ-121^\circ$  for lauroleone which was obtained in a like manner from lauronolic acid.

Five grams of the unsaturated acid was distilled from powdered zinc chloride. The distillate was poured back into the same bulb and distilled again. The distillate was washed with sodium hydroxide solution, dried with  $\text{CaCl}_2$  and then distilled at atmospheric pressure.



| Fraction | Boiling Point | Weight  |
|----------|---------------|---------|
| ( 1      | 118 - 130     | 2.0 gm. |
| A ( 2    | 240 - 260     | 1.0 gm. |
| B - 1    | 115 - 122     | 1.7 gm. |
| C - 1    | 118 - 120     | 1.4 gm. |

The specific gravity was,  $d^{25/4} = .7871$ ;  $d^{20/4} = .7923$ .

The rotation for the liquid hydrocarbon was  $\alpha_D^{23} = -0.7^\circ$ ; for a solution in absolute alcohol containing .0308 gm/cc was  $\alpha_D^{25} = -1.1^\circ$

Eykman<sup>1</sup> gives for lauroleene B.P. =  $119^\circ$ - $120^\circ$  (744 mm);  $d^{17.3/(40)} = .7992$ . Noyes and Burke<sup>2</sup> give B.P. =  $120^\circ$ - $121^\circ$ ;  $\alpha_D^{30} = -5.36$ . Noyes<sup>3</sup> and Derick found for the laevo lauroleene obtained by decomposition of the nitroso derivative from amino-camphonanic anhydride,  $\alpha_D^{20} = -14.5^\circ$ ;  $d^{15/4} = .8043$ .

A discussion of the refractometric constants which were determined for the hydrocarbon will be found on page 82.

As a further means of identification of the acid the preparation of the calcium salt was tried. The unsaturated acid was heated on the steam bath in a flask with water and an excess of finely powdered calcium carbonate. When no more carbon dioxide was evolved, the solution of the calcium salt was filtered and concentrated on the steam bath. The salt represented in the first four analyses was prepared by evaporation in an open dish. In all other cases the evaporation was carried out in an Erlenmeyer flask. In this way the crystals separated throughout the liquid instead of separating at the surface. In the latter case the crystals were transparent prisms with hemihedral facets. In one case from the

1. "Over de Synthese en Structuur van eenige Lauroleen Derivaten"
2. J. Am. Ch. Soc., 34, 180 (J. L. Hoving, Page 60)
3. J. Am. Ch. Soc., 31, 671





acid obtained in the second nitrite decomposition two kinds of crystals were obtained, one consisting of transparent plates and the other of rosettes of radiating fibers. According to analyses No. 5 and No. 6 they contained three and two molecules of water respectively. The acid recovered from the rosettes gave a rotation of  $\alpha_D^{29} = 83.4^\circ$  for a solution in absolute alcohol containing .0156 gm/cc. The weight of the rosettes was nearly four times that of the plates. Two samples of the salt prepared from the acid from the third nitrite decomposition after drying at  $110^\circ$ - $115^\circ$  gave an acid for which  $\alpha_D^{30} = 97^\circ$  (.03134 gm/cc). The recovered acid seemed to be more viscous than before but it did not darken very much. It is interesting to note that the purest acid which has been obtained from the nitrite decomposition gives a rotation which is identical with that recovered from the rosettes.

The analyses are not satisfactory, especially for water of crystallization. Constant weight was never obtained upon heating the beautifully crystalline salt even at the lowest temperatures, and a pleasant odor was always developed even while the salt remained perfectly white. The salt used in the analysis after filtering off the mother liquors was pressed between layers of hardened filter paper and immediately pulverized in an agate mortar. It was neither efflorescent, or deliquescent. The analyses for calcium indicate that the salt contains two molecules of water and is probably mixed with a little of a monohydrated salt. It appeared to be more soluble in cold than in hot water.



Table VII.

| No.     | Sample | Time & Temp.      | Wt. of H <sub>2</sub> O | % H <sub>2</sub> O | Wt. of CaO | % Ca   | CaSO <sub>4</sub> | % Ca   | Av. % Ca |
|---------|--------|-------------------|-------------------------|--------------------|------------|--------|-------------------|--------|----------|
| 1       | .0927  | 1.5hrs<br>125°    | .0145                   | 15.6               | .0124      | 9.55   | .0312             | 9.90   | 9.72     |
| 2       | .1255  | 120               | .0166                   | 13.23              |            |        | .0448             | 10.51* | 10.51    |
| 3       | .1374  | 120°              | .0202                   | 13.90              |            |        | .0490             | 10.50* | 10.50    |
| 4       | .0945  | 110-115           | .0091                   | 9.62               | .0144      | 10.88* | .0342             | 10.75* | 10.81    |
| 5       | .1124  | 110-115<br>plates | .0151                   | 13.43              | .0166      | 10.20  | .0390             | 9.99   | 10.08    |
| 6       | .1452  | 2.5hrs<br>105-110 | .0138                   | 9.50               | .0217      | 10.68* | .0528             | 10.70* | 10.69    |
| 7       | .1359  | 2.5hrs<br>105-110 | .0143                   | 10.52              | .0210      | 11.04* | .0501             | 10.85* | 10.94    |
| 8       | .2045  | 2 hrs<br>110-115  | .0244                   | 11.93              | .0303      | 10.58* | .0721             | 10.38* | 10.48    |
| 9       | .1225  |                   |                         |                    | .0177      | 10.32* | .0446             | 10.70* | 10.51    |
| 10      | .1504  | 3 hrs<br>100-105  | .0153                   | 10.17              | .0224      | 10.64* | .0535             | 10.47* | 10.55    |
| 11      | .1593  | 3 hrs<br>100-105  | .0163                   | 10.23              | .0236      | 10.58* | .0564             | 10.42* | 10.50    |
| 12      | .3055  | 1 hr.<br>105-108  | .0391                   | 12.79              | .0460      | 10.76* | .1097             | 10.57* | 10.66    |
| 13      | .2680  | 1 hr.<br>105-108  | .0307                   | 11.45              | .0404      | 10.77* | .0947             | 10.40* | 10.58    |
| Average |        |                   |                         |                    |            | 10.69  |                   | 10.57  | 10.63    |

|  | H <sub>2</sub> O | Ca     |
|--|------------------|--------|
| Calculated for (C <sub>8</sub> H <sub>13</sub> CO <sub>2</sub> ) <sub>2</sub> Ca.4H <sub>2</sub> O - | 17.21%           | 9.58%  |
| (C <sub>8</sub> H <sub>13</sub> CO <sub>2</sub> ) <sub>2</sub> Ca.3H <sub>2</sub> O -                | 13.49%           | 10.01% |
| (C <sub>8</sub> H <sub>13</sub> CO <sub>2</sub> ) <sub>2</sub> Ca.2H <sub>2</sub> O -                | 9.44%            | 10.48% |
| (C <sub>8</sub> H <sub>13</sub> CO <sub>2</sub> ) <sub>2</sub> Ca.1 1/2H <sub>2</sub> O              | 7.25             | 10.77% |

\*These values were averaged.





## Cis-Camphonolic Acid.

The fractions boiling at 105°-135° (17 mm.) which were obtained from the second nitrite decomposition, were saponified for 48 hours on the steam bath. The alcohol was distilled from a Claisen bulb on the water bath under reduced pressure. The residue was dissolved in water, filtering from any undissolved material. After drying the ether extract from the acidified filtrate, the hydroxy acid was precipitated by the careful addition of petroleum ether. When the fractional crystallization had been repeated a fourth time, the most insoluble fraction gave a constant melting point of 195.5° (Cor). The specific rotation for a solution in absolute alcohol containing .0912 grams/cc was  $\alpha_D^{27^\circ} = 32.1$ . Noyes and Potter found; M.P. = 202-203,  $\alpha_D = 29.2$ . Bredt found; M.P. = 197-198,  $\alpha_D = 29.7$ .

In the later preparations we obtained a purer acid which melted at 201°-202°, but we have not measured the rotation of this yet.

Five-tenths of a gram of the acid melting at 195.5° was heated in a bath of paraffin at a temperature of 255° for 15 minutes. A white crystalline substance sublimed on the sides of the tube. This was shaken with potassium carbonate solution to remove any unchanged acid, and then extracted with ether from which it crystallized in needles. The rotation of the lactone for a solution in absolute alcohol containing .0647 grams/cc was  $\alpha_D^{27^\circ} = -16.8$ . Upon evaporation of the alcohol the crystals melted at 161-162° (Cor). Noyes<sup>1</sup> and Littleton found; M.P. = 160°-162°,  $\alpha_D = -16.1$ . Noyes

1. J. Am. Ch. Soc., 35, 80.



and Potter<sup>1</sup> found; M.P. = 165-167°  $\alpha_D = -22.3$ , Bredt<sup>2</sup> found;  
 $\alpha_D = -16.8$ , M.P. = 161.

The acid was further identified as cis-camphonolic acid by oxidation. Five-tenths of a gram of the acid was placed in a test-tube and to this was added 3 cc. of Beckmann's chromic acid mixture<sup>4</sup>. After standing over night the mixture was diluted with 2 cc. of (1:1) sulphuric acid and allowed to stand 48 hours longer. The dark colored solution was then diluted with two or three volumes of water and extracted with ether. The ether residue was dissolved in benzene and the solution was concentrated on the steam bath until crystallization began. The crystalline product obtained by diluting with an equal volume of petroleum ether melted at 228° (cor). The specific rotation was  $\alpha_D^{30} = -3.9$  for a solution in absolute alcohol containing .0230 grams/cc. Noyes and Potter found for camphononic acid; M. P. = 229-230,  $\alpha_D^{28} = -3.9$  Lapworth and Lenton<sup>5</sup> found M.P. = 228°. Walker and Henderson<sup>6</sup> found M. P. = 228° (Cor.)

Cis-camphonolic acid should give d-camphoric acid through the following series of reactions. (See Page 70)

We resorted to the use of liquid HBr at the temperature of melting CO<sub>2</sub>, fuming HBr, gaseous HBr and gaseous HI in the endeavor to introduce a halogen in the place of the hydroxyl group. Instead of the halogen compound the lactone resulted, or in case the halogen compound was isolated it was so unstable as to spontaneously decompose readily even on standing. The lactone recovered from some of these experiments was placed in a closed dish and sublimed

1. J. Am. Ch. Soc., 34, 66

2. Ann., 366 2

4. Ann., 250, 325

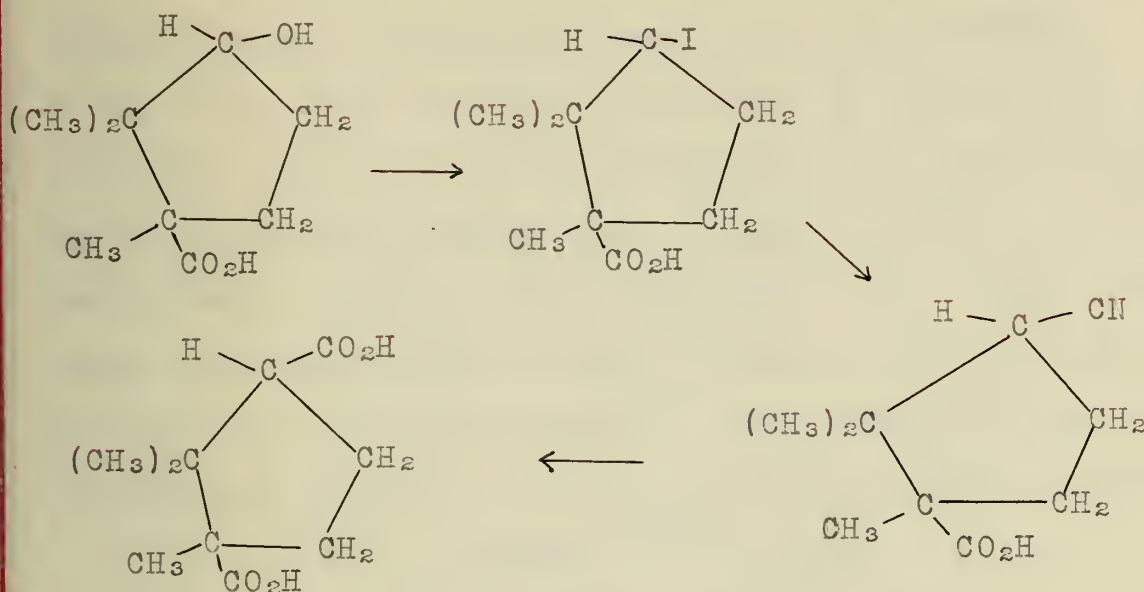
5. J. Ch. Soc., 75, 1000

6. J. Ch. Soc., 69, 755





upon the walls on long standing. The melting point was  $162^{\circ}$ . (Cor)



After it became apparent that the free acid could not be used for this purpose the methyl ester was tried.

Pure cis-camphonolic acid (5.0483 gm) was dissolved in 9.84 cc. of 2.98 N carbonate free sodium hydroxide. To this was added a solution of 5.5 grams silver nitrate dissolved in 10 cc. of water. The silver salt was filtered on a small Hirsch funnel and washed with water, alcohol and ether. The yield was 7.6 grams. Analysis gave the following results.

|                | Sample   | Silver    |        |
|----------------|--|-----------|--------|
| I              | .1678 gm.  | .0651 gm. | 38.58% |
| II             | .1499 gm.  | .0579 gm. | 38.62% |
| Calculated for | $C_8H_{14} \begin{array}{c} OH \\ \diagup \\ CO_2Ag \end{array}$ |           | 38.67% |

Eleven and two-tenths grams of the silver salt covered with absolute ether containing 10.0 grams of methyl iodide was gently heated under a reflux condenser over night. The silver

The first part of the paper discusses the importance of the study of the history of the United States. It is argued that a knowledge of the past is essential for a full understanding of the present. The author then proceeds to a detailed examination of the early years of the Republic, from the time of the signing of the Declaration of Independence to the end of the War of 1812. This section covers the political, social, and economic developments of the period, and the role of the various states in the formation of the new nation. The author also discusses the influence of the Enlightenment on the American mind, and the role of the Founding Fathers in shaping the new government. The second part of the paper deals with the period from 1812 to 1860, and the events leading up to the Civil War. It examines the growing tensions between the North and the South, and the role of slavery in the conflict. The author also discusses the impact of the Industrial Revolution on American society, and the rise of the new political movements of the time. The final part of the paper is a conclusion, in which the author summarizes the main points of the study and offers some thoughts on the future of the United States.

salts were filtered and the ether solution was extracted with 10% sodium carbonate solution to remove the acid substances. The weight of the ester which nearly all distilled at  $130^{\circ}$ - $134^{\circ}$  (19 mm) was 3.2 grams. The weight of the crystalline acid portion was 1.8 grams. The acid obtained from the ester melted not sharply at about  $180^{\circ}$  but not much importance can be attached to this since a very slight trace of impurity causes a large lowering of the melting point. Mixed with an equivalent quantity of the purest acid the melting point rose to 193-195. The ester gave the following constants:

$$d_{20/4} = 1.0535; \quad d_{25/4} = 1.0489$$

$$\text{For the liquid ester } \alpha_D^{26.5} = 32.9$$

$$\text{For a solution in absolute alcohol containing .09916 gm/cc, } \alpha_D^{25.5} = 34.0$$

In one of the representative experiments .5 gm of the ester was dissolved in  $\text{CS}_2$ . The U-tube was suspended in a freezing mixture of hydrochloric acid and ice. Gaseous hydrogen iodide was passed into the solution. The iodide is quite soluble in  $\text{CS}_2$  but in this manner some light yellow crystals separated. The  $\text{CS}_2$  solution was poured off and evaporated in a stream of dry air. A brown liquid remained at room temperature, which was allowed to stand 24 hours open to the air in order to get a measure of its degree of composition. Free iodine separated. .1434 gm sample gave .0526 gm. AgI corresponding to 19.8% of iodine. The theory requires 42.9% so that taking into consideration the free iodine it was evident that the compound was too unstable to work with.

The U-tube in which the crystals remained was placed in a freezing mixture and quickly evacuated with the pump in order to





remove the last of the solvent. It was then wiped dry and weighed as quickly as possible estimating to the nearest milligram. The crystals melted below room temperature. The contents of the U-tube (.556 gm) was washed into 100 cc. volumetric flask with alcohol and made up to the mark with alcohol and water. Twenty-five cc. samples of this solution were analyzed with the following results:

| Sample   | AgI   | Ag    |
|--|-------|-------|
| .139 gm  | .0878 | 34.1% |
| .139 gm  | .0870 | 33.8% |
| .139 gm  | .0878 | 34.1% |
| Calculated for $\text{C}_8\text{H}_{14}\overset{\text{I}}{\text{CO}_2\text{CH}_3}$ |       | 42.9% |

To the crystalline iodide from .5 gm of the ester was added directly 25 cc of a saturated solution of KCN in methyl alcohol. The methyl alcohol was distilled under diminished pressure. The residue was taken up in water and ether. A viscous oil was left from the evaporation of the ether which did not give ammonia when dropped on hot soda-lime or Prussian blue after fused with sodium.

The entire acid portion (3.3 gm) obtained in the preparation of the methyl ester of cis-camphonolic acid from the silver salt was dissolved in a small volume of benzene with warming. The solution was cooled and two volumes of petroleum ether were added, with stirring, to precipitate the cis-camphonolic acid. The precipitate weighed .8 gm and the melting point was not sharp at 188-190°. The weight of the crystals obtained from the mother liquors was 2 grams and melted at 70°-75°. This mixture of acids was dissolved in the theoretical quantity of NaOH solution. To obtain the first fraction half the theoretical quantity of HCl solution was added the



the mixture was allowed to stand over night before filtering on a small Hirsch funnel. The second fraction was obtained by complete acidification.

Table VIII.

| Acid          | :2.98 N:<br>:NaOH | : 2.88 N<br>: HCl | : First<br>: Fraction | : Second<br>: Fraction | : Ether<br>: Ext.   |
|---------------|-------------------|-------------------|-----------------------|------------------------|---------------------|
|               |                   |                   | :<br>:gm<br>:No.:Wt   | :<br>:gm<br>:No :Wt.   | :<br>:M.P.<br>:M.P. |
| 1.891 gm      | :3.54cc           | :1.83+ 2cc        | :A-1: .813            | :A-2: .893             | :66-68              |
| (A-1)+(A-3)   | :1.69             | :.87 + 2cc        | :B-1: .347            | :B-2: .523             | :80-84              |
| A-2           | :1.67             | :.87 + 2cc        | :B-1: .318            | :B-2: .382             | :81-85              |
| (B-1) + (B-1) | :1.24             | :.64              | :C-1: .238            | :C-2: .260             | :86-87              |
| (B-2) + (B-2) | :1.69             | :.57              | :C-1: .097            | :C-2: .561             | :86-87              |

Fraction C-2 when mixed with an equivalent weight of the decomposition methyl ether of the acid obtained in the nitrite, gave a mixed melting point of 86.5 -87.5. The mixed melting point for C'-2 was 86-87.5. The two are therefore identical, and are identified as the methyl ether of cis-camphonolic acid.

An attempt to prepare the methyl ether of ciscamphonolic ester by the action of methyl iodide on the sodium salt resulted merely in the saponification of the ester. It is hoped to repeat this more carefully.

#### The Other Hydroxy Acids.

The acid obtained from the saponification of the ester boiling at 112-114° (18 mm) distilled mostly at 180-182° (18 mm). Five





and five-tenths grams of the ester yield 4 grams of the acid which had a slightly greenish tint. The silver salt precipitated from a solution of the calcium salt and dried in a water oven, under which treatment it darkened slightly, gave the following analysis:

.1063 gm. gave .0413 gm Ag or 38.85%

.1187 gm. gave .0462 gm Ag or 38.92%

Calculated for  $C_8H_{14}-\overset{OH}{\diagup}CO_2Ag$  38.67%

The solution of the calcium salt was concentrated to a small volume on the steam bath and then finally in a vacuum desiccator over calcium chloride. A white crystalline salt separated which was filtered off on a Hirsch funnel. The mother liquors upon complete evaporation left a substance which looked like glue and did not crystallize. The analysis of the crystalline salt dried at 100° is as follows:

.1923 gm. heated at 155-160° for one hour; gave .0097 gm.  $H_2O$ , .0266 gm  $CaO$ , and .0659 gm.  $CaSO_4$ .

.1947 gm. gave .0097 gm  $H_2O$ , .0268 gm.  $CaO$  and .0657 gm.  $CaSO_4$

|    | $H_2O$ | $Ca$  |
|----|--------|-------|
| I  | 5.0%   | 9.98% |
| II | 4.9%   | 9.88% |

Calculated for  $(C_8H_{14}-\overset{OH}{\diagup}CO_2)_2Ca \cdot H_2O$  4.50% 10.01%

In the next experiment 10 grams of the ester yielded 7 grams of the acid boiling mostly at 180-182° (18 mm). While preparations were being made to convert the acid into the calcium salt crystals began to appear in the receiving bulb. A small portion of the crystalline material was fished out on the point of a glass rod and allowed to stand on porous porcelain to absorb the oily material.



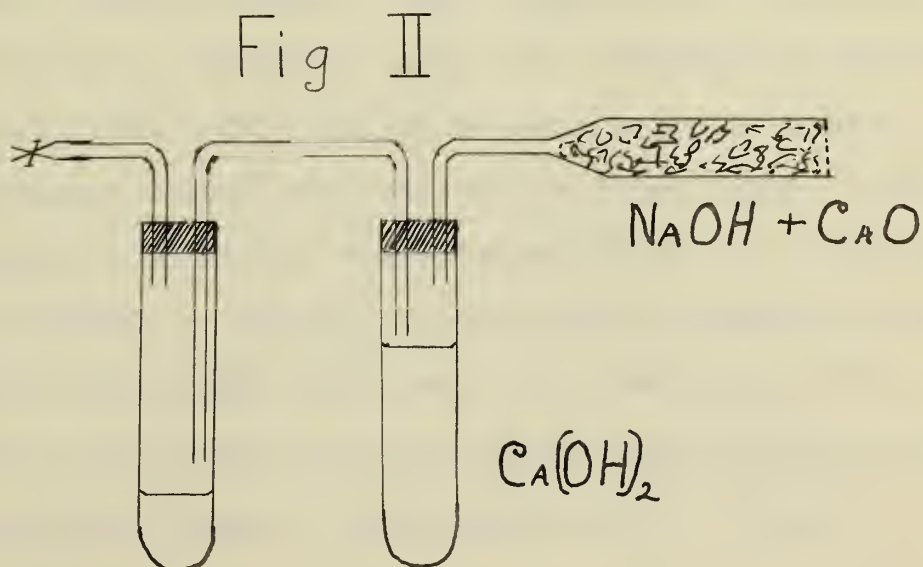
M.P. = 80-95°. They dissolved immediately in 10%  $\text{Na}_2\text{CO}_3$  solution with the evolution of carbon dioxide. The resulting solution was stable toward dilute  $\text{KMnO}_4$ . To the entire amount of the acid in the bulb a little petroleum ether was added and the mixture was cooled in a freezing mixture. The white silky crystals were filtered on a Hirsch funnel. M.P. = 80-95. Weight = 1.5 gm. The material was then dissolved in a little hot benzene. An equal volume of ligroin (B.P. = 70°) was added and the solution was concentrated to a small volume. On cooling it solidified to a white solid mass of silky needles, which melted at 95 - 100°. Weight 1.1 gm. One more crystallization gave 1 gm. of the acid melting at 100-102. The best way to purify the acid is to crystallize the sodium salt.

.1094 gm. required 12.78 cc .04979 N KOH for neutralization

Calculated for  $\text{C}_8\text{H}_{14}-\overset{\text{OH}}{\text{CO}_2\text{H}}$  12.76 cc.

The rotation for a solution in absolute alcohol containing .07016 gm/cc was  $\alpha_D^{26} = 35.6^\circ$

Five-tenths of a gram of the acid was treated with 3 cc of Beckmann's mixture in the following apparatus.







After standing fifty-four hours there was scarcely any darkening of the dichromate. At this point 2 cc of (1:1) sulphuric acid was added\*, after which unmistakable evidences of  $\text{CO}_2$  were obtained.

After standing 40 hours longer the solution had turned green and considerable calcium carbonate had precipitated. The hydroxy acid was recovered practically unchanged, the specific rotation for a solution of crude acid in absolute alcohol containing .0777 gm/cc being,  $\alpha_D = 34^\circ$ . The recovered acid was distilled with the chromic acid mixture giving a few drops of an oil slightly heavier than water. (An unsaturated acid? This point was not tested out) It gave a slight but unmistakable test for the  $>\text{C} = \text{O}$  group with phenyl hydrazine.

The liquid residue from the evaporation of the petroleum ether mother liquors did not dissolve completely in sodium carbonate solution. The lactone portion had an odor resembling isocampholactone and upon standing in a freezing mixture of hydrochloric acid and ice it crystallized. It has not been further investigated. The acid portion did not crystallize although it became very viscous. This acid would of course contain a very little of the crystalline acid. As a preliminary experiment .5 gm was oxidized in the manner used for the crystalline acid. The dichromate began to darken immediately. Evidence of  $\text{CO}_2$  was obtained in three hours. After standing eight hours the mixture was diluted with 2 cc. of dilute (1:1)  $\text{H}_2\text{SO}_4$  and allowed to stand forty hours with occasional shaking. Not quite as much  $\text{CaCO}_3$  was formed as in the case of the crystalline acid. The residue from the ether extract was distilled with steam. No oil separated in the distillate but it gave a



decided test for the carbonyl group with phenylhydrazine. The precipitate was non-crystalline and too small in amount to investigate. The phenyl hydrazone of the non-volatile portion precipitated as a gummy substance. It was mainly insoluble in ammonium hydroxide. The rotation of this acid was  $\alpha_D^{23.5} = 11.5^\circ$  for a solution in absolute alcohol containing .09824 gm/cc.

.1041 gm. of the silver salt gave .0400 gm. of silver corresponding to 38.61%.  $\text{C}_8\text{H}_{14}\overset{\text{OH}}{\text{---}}\text{CO}_2\text{Ag}$  requires 38.67%

Five-tenths of a gram of the crystalline hydroxy acid was suspended in carbon disulphide and kept cold in a freezing mixture. Gaseous hydrogen iodide was passed in until solution resulted. The yellow crystals left on evaporation of the carbon disulphide melted fairly sharply at  $85-87^\circ$  although there was some decomposition. Upon standing the product decomposed. The carbon disulphide solution of iodide after partial evaporation was shaken at once with sodium hydroxide solution. Merely sulphur remained in the carbon disulphide layer, no lactone being formed. The acid instantly reduced dilute permanganate. The rotation for a solution in absolute alcohol containing .04104 gm/cc was  $\alpha_D^{25^\circ} = 142^\circ$ . This is in as good agreement with that of lauronic acid as could be expected, since the rotation of this acid has been shown to vary. The brom-lactone melted at  $193-194^\circ$  and was shown to be identical with the brom-lactone from lauronic acid by a determination of the mixed melting point.

The liquid hydroxy acid from which the above crystalline hydroxy acid was separated was treated with gaseous hydrogen iodide in the same manner to obtain the unsaturated acid. A lactone was





also obtained which melted at  $47^{\circ}$ - $48^{\circ}$ . This was shown to be identical with campholactone by a determination of the melting point. The rotation for a solution in absolute alcohol containing .03312 gm/cc was  $\alpha_D^{26} = 88.4$ . The brom-lactone after steam distillation melted at 189-191 and was shown to be identical with the brom lactone from the unsaturated acid obtained in the nitrite decomposition.

The method finally adopted in the separation of cis-camphonolic, the crystalline and liquid hydroxy acids from the intermediate fractions is given diagrammatically as follows:

Concentrated Ether solution

Petroleum Ether

| Insoluble             |   | Soluble  |
|-----------------------|---|--|
| Cis-camphonolic acid. | ↓   | Calcium Salt.  |
|                       | ↓   |  |
|                       | Insoluble   | Soluble  |
|                       | Ca Salt of acid M.P. 101-102:   | ↓ Concentration  |
|                       | ↓ Na Salt   | Crystalline : Non-Crystalline  |
|                       | Na Salt crystallizes from hot concentrated solution in long white needles | Ca Salts of acid M.P. = 101-102 and cis-camphonolic acid : Ca Salt of liquid hydroxy acid as a syrupy liquid |
|                       | ↓ Na Salt   |  |
|                       | In- : sol'bl : acid : M.P. = 101-102 : acid :                             | Sol'bl : cis- : campho- : nolic : acid :   |



Decomposition of Methyl Amino-Camphonanate and Methyl  
Aminodihydro-campholytate.

The formation of the methyl ether of cis-camphonolic acid under the conditions of the experiment was so unexpected that the methyl esters of two other amino acids in this series were decomposed in order to see if a similar result would be obtained.

The method used in preparing the methyl ester of aminocamphonanic acid was in general that used in the preparation of the methyl ester of isoaminocamphonanic acid. However, very poor yields were obtained in the hypobromite reaction and the initial preparation of the amino acid<sup>1</sup> and subsequent esterification is to be recommended.

Dimethyl d-camphorate boiled at 155° (25 mm) or 144° (15 mm). The rotation for the liquid ester was  $\alpha_D^{29} = 47.5$ , for a solution in absolute alcohol containing .1036 gm/cc,  $\alpha_D^{31} = 45.8^\circ$ .  $d_{20/4}^{20/4} = 1.0768$ .  $d_{25/4}^{25/4} = 1.0727$ .

The B-methyl  $\alpha$ , d-camphoramidate melted at 154-155°. The rotation for a solution in absolute alcohol containing .0974 gm/cc was  $\alpha_D^{28} = 23.1^\circ$ .

Three hundred and seventy grams of the amide ester gave 84 grams of the hydrochloride of the amine ester. M.P. = 237°. The rotation for solution in absolute alcohol containing .1073 gm/cc was  $\alpha_D^{30} = 26.2^\circ$ . The examination of the side products is not complete.

Seventy-nine grams of hydrochloride was decomposed with sodium nitrite in slightly acid solution. No ether acid was obtained upon extracting the products with a solution of sodium carbonate. The

-----





first distillation gave the following fractions:-

| <u>No</u> | <u>B.P.</u> | <u>Bath</u> | <u>Pressure</u> | <u>Weight</u> |
|-----------|-------------|-------------|-----------------|---------------|
| 1         | Below 105°  | 115-130°    | 20-18 mm        | 31.5 gm       |
| 2         | 105-120°    | 130-145°    | 20 mm.          | 8.1 gm        |
| 3         | 115-135     | 140-175°    | 17 mm.          | 10.3 gm       |

After fractionating twice more 18.2 grams of an ester boiling at 78-85° (15 mm) was obtained. The rotation for a solution in absolute alcohol containing .0925 gm/cc was  $\alpha_D^{28.5^\circ} = 73.8^\circ$

From this ester 14.1 grams of the unsaturated acid boiling at 125-130° (10 mm) was obtained.  $d^{25/4} = 1.0090$ .  $d^{20/4} = 1.0130$   
The rotation for the liquid acid was  $\alpha_D^{28.5^\circ} = 108.1^\circ$ , and for a solution in absolute alcohol containing .09614 grams/cc it was  $\alpha_D^{27.5^\circ} = 85.3^\circ$ . The acid is therefore identical with the unsaturated acid obtained in the decomposition of the isomeric ester.

Methyl aminodihydrocampholytate was prepared by esterifying the crude amino acid from  $\beta$ -d-camphoramidic acid. Seventy-nine and six-tenths grams of  $\beta$ -d-camphoramidic acid gave 64 grams of the hydrochloride. This melted sharply to a clear liquid at 186.5°. The rotation for a solution in absolute alcohol containing .04684 gm/cc was  $\alpha_D^{26.5^\circ} = 48.8^\circ$

No ether acid was obtained. The esters at the second fractional distillation gave the following fractions.

| <u>No.</u> | <u>B.P.</u> | <u>Bath</u> | <u>Pressure</u> | <u>Weight</u> |
|------------|-------------|-------------|-----------------|---------------|
| 1          | 80-90°      | 110-125°    | 15 mm.          | 8.8 gm        |
| 2          | 90-115      | 125-145     | 15 mm.          | 1.3 gm        |
| 3          | 115-125     | 150         | 15 mm.          | 1.3 gm.       |
| 4          | 116-123     | 140-145     | 10 mm.          | 7.3 gm.       |



### The Ether Acid from Isocampholactone.

Noyes and Taveau<sup>1</sup> obtained an ether acid, which melted at 84° by treating the silver salt of the hydroxy acid derived from isocampholactone with methyl iodide. The writer has repeated this work in order to see if it were identical with the methyl ether of cis-camphonolic acid.

Sixteen and five-tenths grams of the silver salt was warmed gently under a reflux for seven hours with 8.5 grams of methyl iodide. The fraction soluble in sodium carbonate solution weighed .4 grams and the melting point of a few selected crystals was 84° (cor.) When mixed with an equivalent weight of cis-camphonolic methyl ether the melting point was not sharp at about 50°. The two are therefore different. The rotation for a solution in absolute alcohol containing .0844 gm/cc was  $\alpha_D^{29} = 69.9^\circ$

### Lauronolic Acid.

Lauronolic acid was prepared from d, brom-camphoric anhydride, according to the method of Aschan<sup>2</sup>. Four hundred grams of camphoric acid worked up in 200 grams lots gave 264 grams of d-brom camphoric anhydride after crystallizing from glacial acetic acid. The melting point was 215-216° (uncor) or 222° (cor.)\*. Aschan gives the melting point as 214° and a much larger yield probably due to the fact that he worked with smaller quantities.

The anhydride (200 grams) was digested on the steam bath over night with a solution of 90 gm Na<sub>2</sub>CO<sub>3</sub> in 510 cc of water. Solution

1. J. Am. Chem., 35, 381

2. Ber., 27, 3504

\* Anschütz Thermometer.





was not quite complete and the insoluble residue was filtered off. The filtrate was treated with 13 cc  $\text{H}_2\text{SO}_4$  (1.84) and steam distilled. It was noticed that the liquid became clear a long time before the distillate did. To the distillate (about 2 liters) was added a quantity of salt. The acid was then extracted with ether. It boiled constantly at  $139-140^\circ$  (17 mm). The yield was 12 grams or 10% of the theory and the yield of camphanic acid was 99 grams. The rotation for a solution in absolute alcohol containing .04535 gm/cc

$\alpha_D^{25^\circ} = 152^\circ$  and for the liquid acid,  $\alpha_D^{25.5} = 191^\circ$  Noyes and Burke give,  $\alpha_D^{25} = 187.7^\circ$  and Tiemann<sup>1</sup> gives  $\alpha_D^{19^\circ} = 199^\circ$ .

The Br-lactone of the above acid after repeated crystallization from hot ligroin melted constantly at  $193-194^\circ$ . When mixed with an equal quantity of the unsaturated acid from methyl isoaminocamphanate the melting point was  $193-194^\circ$ . The rotation for a solution in absolute alcohol containing .04592 grams/cc was  $\alpha_D^{25^\circ} = 51.0$ . It gave the same campholactone and the same hydroxy acid.

A sample of lauronolic acid having a rotation of  $\alpha_D^{24.5^\circ} = 186^\circ$  was converted to laurolene by distilling with anhydrous zinc chloride. The index of refraction for this sample of lauronolic acid<sup>2</sup> was as follows:

|               |            |           |
|---------------|------------|-----------|
|               | $n_D^{25}$ | = 1.47689 |
|               | $n_D^{25}$ | = 1.47922 |
| Eykman gives: | $n_D^{25}$ | = 1.48652 |
| $n_C^{16.7}$  | = 1.47602  |           |
| $n_F^{16.7}$  | = 1.48649  |           |
| $n_G^{16.7}$  | = 1.49273  |           |

|                  |           |
|------------------|-----------|
| Burke Gives:     |           |
| $n_C^{20}$       | = 1.47269 |
| $n_D^{20}$       | = 1.47586 |
| $n_F^{20}$       | = 1.48323 |
| $n_G^{20^\circ}$ | = 1.48904 |



Four and five-tenths grams gave, upon distilling a second time from  $\text{Zn Cl}_2$ , .9 gram of a hydrocarbon boiling at 118-122 which had been washed with sodium hydroxide solution and water before drying with calcium chloride. The refractometric data for this hydrocarbon is given in column I, that for the hydrocarbon obtained from the unsaturated acid resulting in the nitrite decomposition in column II. Eykman's data for lauroleone (B.P. 119-120°) is given in column III.

Table IX.

| Refractive Index |         |         |         |         |       |
|------------------|---------|---------|---------|---------|-------|
| NO.              | C       | D       | F       | G'      | Temp  |
| I                | 1.43972 | 1.44315 | 1.44988 | 1.45555 | 25°   |
| II               | 1.44121 | 1.44426 | 1.45099 | 1.45695 | 25°   |
| III              | 1.44435 |         | 1.45438 | 1.46041 | 17.3° |

| Dispersion. |        |        |        |        |        |        |
|-------------|--------|--------|--------|--------|--------|--------|
| NO          | D-C    | F-C    | G'-C   | F-D    | G'-D   | G'-F   |
| I           | .00343 | .01016 | .01583 | .00673 | .01240 | .00567 |
| II          | .00305 | .00978 | .01574 | .00673 | .01269 | .00596 |
| III         |        | .01003 | .01606 | .      |        | .00603 |





Table X.

## Molecular Refractive Power.

| Gladstone and Dale |         |          |          | Lorenz - Lorentz |          |          |          |          |
|--------------------|---------|----------|----------|------------------|----------|----------|----------|----------|
| No.                | C       | D        | F        | G'               | C        | D        | F        | G'       |
| I                  | :61.513 | : 61.993 | : 62.934 | : 63.727         | : 36.848 | : 37.077 | : 37.584 | : 37.994 |
| II                 | :61.721 | : 62.149 | : 63.090 | : 63.923         | : 36.957 | : 37.156 | : 37.677 | : 38.095 |
| III                | :61.160 | :        | : 62.541 | : 63.371         | : 36.586 | :        | : 37.300 | : 37.727 |

## Eykmann.

|     |         |          |          |          |                |
|-----|---------|----------|----------|----------|----------------|
| I   | :81.576 | : 82.126 | : 83.343 | : 84.332 | M. V. = 139.89 |
| II  | :81.835 | : 82.298 | : 83.543 | : 84.576 | M. V. = 139.89 |
| III | :81.057 | :        | : 82.877 | : 83.809 | M. V. = 137.64 |

Table XI.

| Gladstone and Dale |           |           |            |           |            |            | Lorenz-Lorentz |           |            |           |
|--------------------|-----------|-----------|------------|-----------|------------|------------|----------------|-----------|------------|-----------|
| No.                | $r_{D-C}$ | $r_{F-C}$ | $r_{G'-C}$ | $r_{F-D}$ | $r_{G'-D}$ | $r_{G'-F}$ | $r_{D-C}$      | $r_{F-C}$ | $r_{G'-C}$ | $r_{F-D}$ |
| I                  | .48       | 1.42      | 2.21       | .94       | 1.73       | .79        | .23            | .74       | 1.15       | .51       |
| II                 | .43       | 1.37      | 2.20       | .94       | 1.77       | .83        | .20            | .72       | 1.14       | .52       |
| III                |           | 1.38      | 2.21       |           |            | .83        |                | .71       | 1.14       |           |

| Lorenz-Lorentz |            |            |           |           | Eykmann   |            |            |            |  |
|----------------|------------|------------|-----------|-----------|-----------|------------|------------|------------|--|
| No.            | $r_{G'-D}$ | $r_{G'-F}$ | $r_{D-C}$ | $r_{F-C}$ | $r_{F-D}$ | $r_{G'-D}$ | $r_{G'-F}$ | $r_{G'-C}$ |  |
| I              | : .92      | : .41      | : .55     | : 1.77    | : 1.22    | : 2.21     | : .99      | : 2.76     |  |
| II             | : .94      | : .42      | : .46     | : 1.71    | : 1.25    | : 2.28     | : 1.03     | : 2.74     |  |
| III            | :          | : .43      | :         | : 1.82*   | :         | : .93*     | : 2.75*    | :          |  |

\* On page 30 of J.L. Hoving's book the values from Perkin's data are respectively 1.71, 1.03 and 2.74, which are in exact agreement with our data, although the figures on page 60 give the results indicated.



Table XII.

|                         | G & D     |            | L & L     |            | E    |      |
|-------------------------|-----------|------------|-----------|------------|------|------|
|                         | $r_{F-C}$ | $r_{G'-C}$ | $r_{F-C}$ | $r_{G'-C}$ |      |      |
| Increments for one (=). | .07       | .12        | .03       | .05        | .08  | .14  |
| Hydrolaurolene          | 1.09      | 1.72       | .575      | .91        | 1.37 | 2.16 |
| Laurolene               | 1.37      | 2.20       | .71       | 1.135      | 1.71 | 2.74 |
| Difference              | -.28      | -.48       | -.1.35    | -.225      | -.34 | -.58 |

Eykmann also calculated the specific refractive power of laurolene from data taken at  $80.5^{\circ}$  with results practically identical with those at  $17.3^{\circ}$ . It is therefore allowable to compare our results at  $25^{\circ}$  with his. The index of refraction for our hydrocarbons increases as the temperature falls. In calculating the molecular volume at  $25^{\circ}$  of the laurolene obtained from lauronolic acid the density of the hydrocarbon obtained from the unsaturated acid of the nitrite decomposition was used. The former was not as pure as the latter. The molecular refractive powers were calculated according to the following formulae:

Gladstone and Dale

$$r = (N_D - 1) M.V.$$

Lorenz-Lorentz

$$r = \frac{N_D^2 - 1}{N_D + 2} M.V.$$

Eykmann

$$r = \frac{N_D^2 - 1}{N_D + 4} M.V.$$

The results\* point rather strongly to the conclusion that the hydrocarbon from the unsaturated acid is pure laurolene.

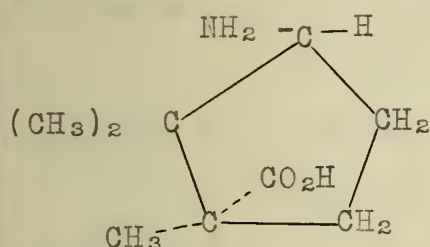
\* This Thesis, Page 23





## Structure of Isoaminocamphonanil Acid.

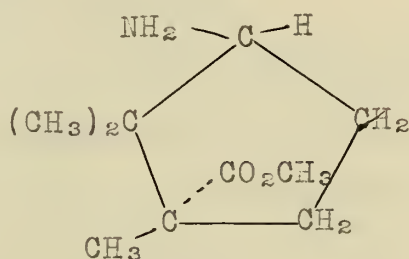
The optical rotation has been determined for isoaminocamphonanil acid and a series of compounds derived from it to supplement Noyes<sup>1</sup> and Potter's work on the valence of nitrogen in ammonium salts. The inner salt is evidently not formed.



Isoaminocamphonanil Acid

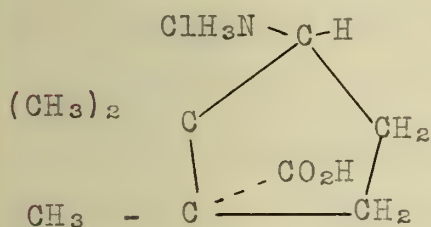
$$\alpha_D^{23^\circ} = -33.8^\circ$$

$$(C) = .08852 \text{ gm/cc (water)}$$



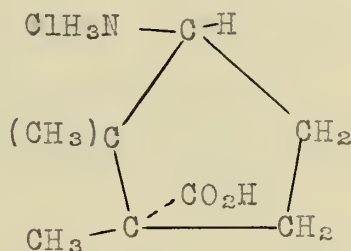
$$\alpha_D^{25^\circ} = -41.2^\circ$$

$$(C) = .1048 \text{ gm/cc (alcohol)}$$



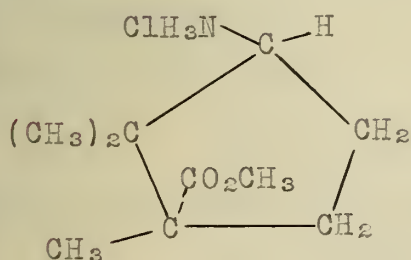
$$\alpha_D^{25^\circ} = -28.8^\circ$$

$$(C) = .1115 \text{ gm/cc (water)}$$



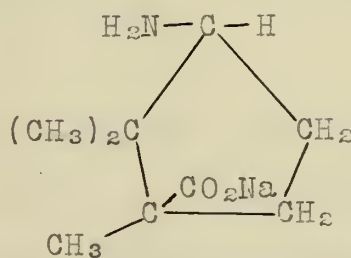
$$\alpha_D^{25^\circ} = -37.8^\circ$$

$$(C) = .05127 \text{ gm/cc (alcohol)}$$



$$\alpha_D^{25^\circ} = -42.2^\circ$$

$$(C) = .0883 \text{ gm/cc (alcohol)}$$



$$\alpha_D^{25^\circ} = -18.0$$

$$(C) = .1027 \text{ gm/cc (water)}$$



## CONCLUSIONS. IV

This investigation is far from complete and, if opportunity offers, it is the intention of the writer to spend a month or two in establishing upon a surer basis some of the conclusions to which he has been led by the results already obtained.

1. The method of preparation of methyl isoaminocamphonanate has been improved and its physical constants have been determined.

2. In the nitrite decomposition the methyl ester of an unsaturated acid, the methyl ether of a hydroxy acid and the methyl esters of at least three hydroxy acids are formed. No hydrocarbon was obtained.

3. The unsaturated acid has been shown in a variety of ways to be lauronolic acid, but it has been shown to contain 5 - 10% of a new compound, 1,2,2 trimethyl 2 - pentenoic acid.

4. The ether acid has been definitely shown to be the methyl ether of cis-camphonolic acid.

5. One of the hydroxy acids is cis-camphonolic acid.

6. The evidence that the crystalline hydroxy acid melting at 101-102 is 1,2,3 trimethyl 2-Cis-hydroxy 1-cyclopentanoic acid is as follows:

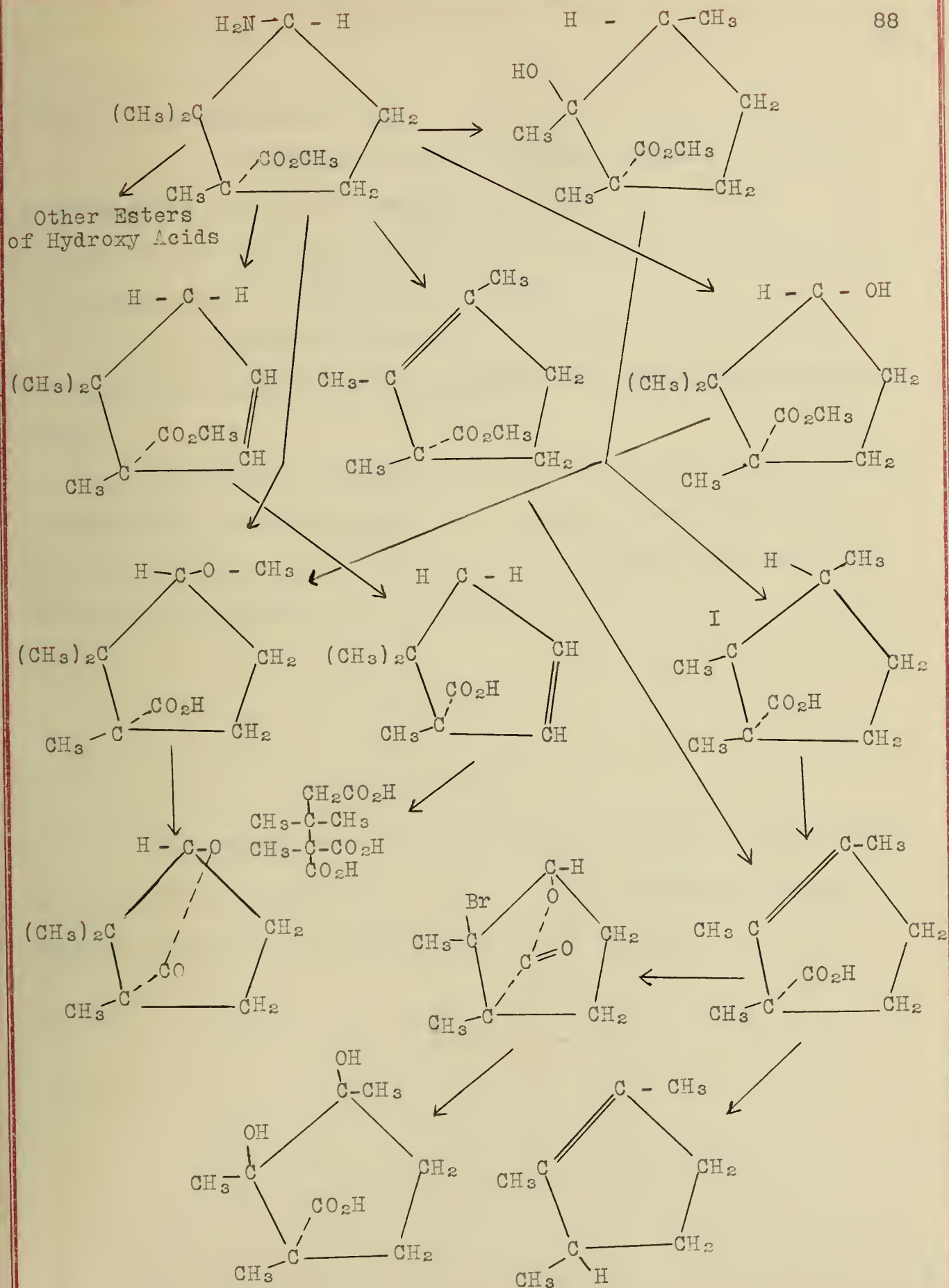
(a) It is not oxidized by Beckmann's chromic acid mixture in the cold and does not give a lactone by this treatment.

(b) It gives a comparatively stable crystalline iodide, which gives lauronolic acid and no lactone when treated at once with sodium hydroxide solution.

(c) Its rotation is even more strongly positive than









that for cis-camphonolic acid.

7. The other hydroxy acid probably contains a secondary hydroxyl group since it is readily oxidized.

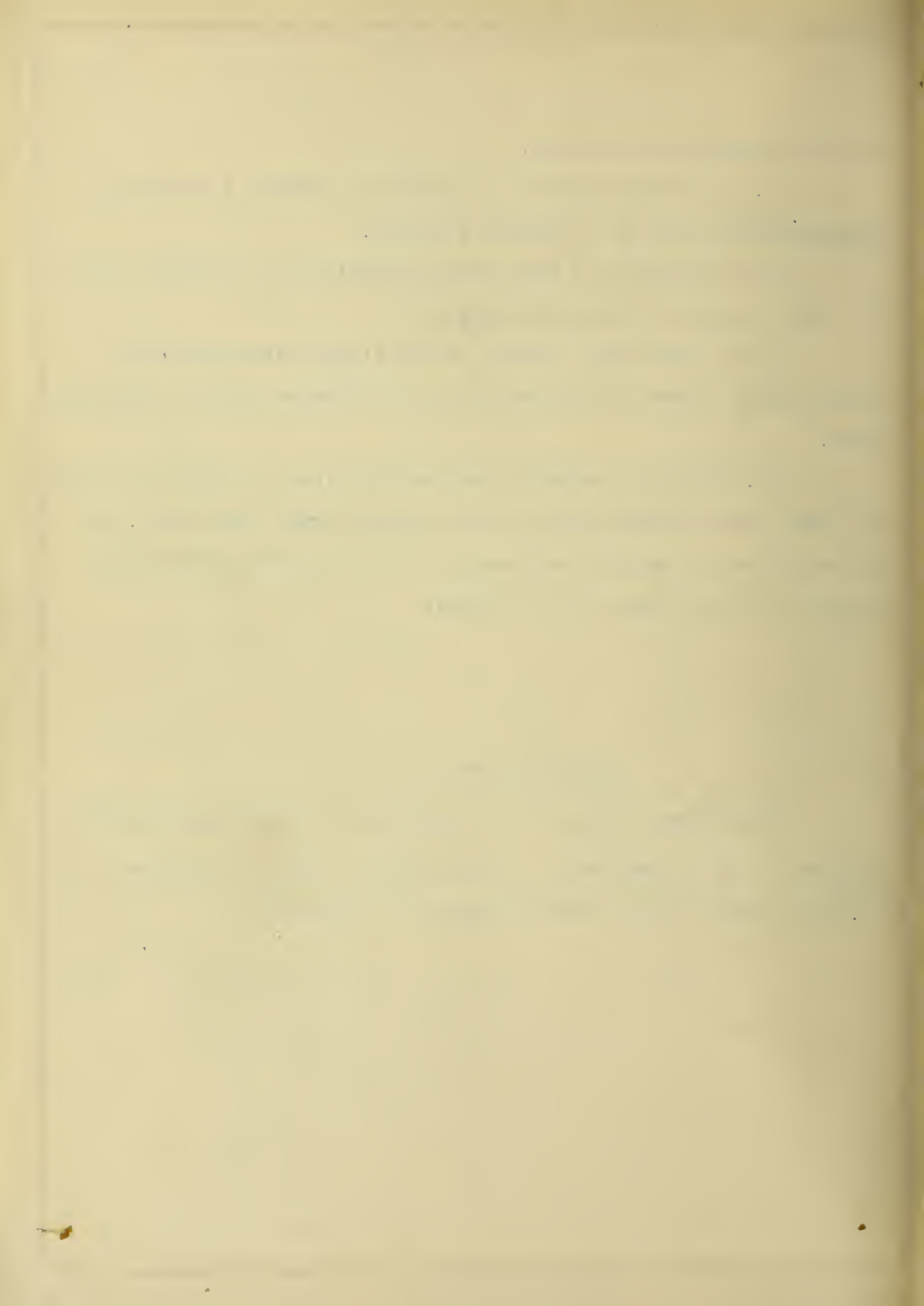
8. The ether acid from isocampholactone is different from the methyl ether of cis-camphonolic acid.

9. No ether acid results in the nitrite decomposition of the methyl esters of aminocamphonanic and amino dihydrocampholytic acids.

10. Additional evidence has been obtained in support of the view that the cis amino acids in this series form inner salts, as the rotations of isoaminocamphonanic acid and certain derivatives indicate that no inner salt is formed.

#### Acknowledgment.

The present research was undertaken at the suggestion of Professor W. A. Noyes, and to him the writer wishes to express sincere thanks for his kindly interest in the work.





### Vita.

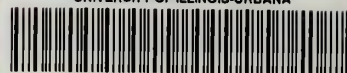
The writer was born on a farm near Columbus, Kansas, June 1, 1890. He graduated from the College Preparatory Course in the Crawford County High School in 1909. In September of the same year he entered the Kansas State Normal at Pittsburg, graduating in June, 1913 with the degree of Bachelor of Arts. He was an assistant instructor in chemistry and physics at that institution for the summer session of the same year. Coming to the University of Illinois in September, 1913, he was appointed Graduate Assistant in Chemistry the following February, and graduated in June, 1915 with the degree of Master of Arts. He was appointed Assistant in Chemistry for the next two years and continued the research work presented in the Master's Thesis.

The writer was elected to membership in the Alpha Chapter of Phi Lambda Upsilon in 1914 and to the Illinois Chapter of Sigma Xi in 1916.





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